VAMP 210

Generator protection relay

Publication version: V210/EN M/A011

User manual

Schneider Electric

Table of Contents

1. General

This first part (Operation and configuration) of the publication contains general descriptions of the functions, of the generator protection relay as well as operation instructions. It also includes instructions for parameterization and configuration of the relay and instructions for changing settings.

The second part (Technical description) of the publication includes detailed protection function descriptions as well as application examples and technical data sheets.

1.1. Relay features

The comprehensive protection functions of the relay make it ideal for utility, industrial, marine and off-shore power distribution applications. The relay features the following protection functions.

List of protection functions

IEEE/ ANSI code	IEC symbol	Function name
50/51	3I>, 3I>>, 3I>>>	Overcurrent protection
67	I_{dir}>, I_{dir}>>, I_{dir}>>>, I_{dir}>>>>	Directional overcurrent protection
51V	Iv>	Voltage restrained or voltage controlled overcurrent function
46	I_2>	Current unbalance protection
49	T>	Thermal overload protection
50N/51N	I_0>, I_0>>, I_0>>>, I_0>>>>	Earth fault protection
67N	$I_{0\varphi}$>, $I_{0\varphi}$>>	Directional earth fault protection
67NT	I_{0T}	Intermittent transient earth fault protection
59	U>, U>>, U>>>	Overvoltage protection
27	U<, U<<, U<<<	Undervoltage protection
24	U/f>	Volts/hertz overexcitation protection
27P	U_1<, U_1<<	Positive sequence undervoltage protection
59N	U_0>, U_0>>	Residual voltage protection
64F3	U_{0f3}<	100 % stator earth fault protection
81H/81L	f><, f>><<	Overfrequency and underfrequency protection
81L	f<, f<<	Under frequency protection
81R	df/dt>	Rate of change of frequency (ROCOF) protection
21	Z<, Z<<	Underimpedance protection
40	Q<	Underexcitation protection
21/40	X<, X<<	Underreactance protection (Loss of excitation)
32	P<, P<<	Reverse and underpower protection
51F2	I_{f2}>	Second harmonic O/C stage
51F5	I_{f5}>	Fifth harmonic O/C stage
50BF	CBFP	Circuit-breaker failure protection
99	Prg1...8	Programmable stages

IEEE/ ANSI code	IEC symbol	Function name
50ARC 50NARC	ArcI>, $ArcI_{01}>$, $ArcI_{02}>$	Optional arc fault protection

Further the relay includes a disturbance recorder. Arc protection is optionally available.

The relay communicates with other systems using common protocols, such as the Modbus RTU, ModbusTCP, Profibus DP, IEC 60870-5-101,IEC 60870-5-103, IEC 61850, SPA bus Ethernet / IP and DNP 3.0.

1.2. User interface

The relay can be controlled in three ways:

- Locally with the push-buttons on the relay front panel
- Locally using a PC connected to the serial port on the front panel or on the rear panel of the relay (both cannot be used simultaneously)
- Via remote control over the remote control port on the relay rear panel.

1.3. Operating Safety

⚠ WARNING

HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH

A live current transformer secondary circuit must not be opened without turning off the primary side of the transformer and short circuiting transformer secondary circuits first

Failure to follow these instructions can result in death, serious injury, or equipment damage

2. Local panel user interface

2.1. Relay front panel

The figure below shows, as an example, the front panel of the relay VAMP 210 and the location of the user interface elements used for local control.

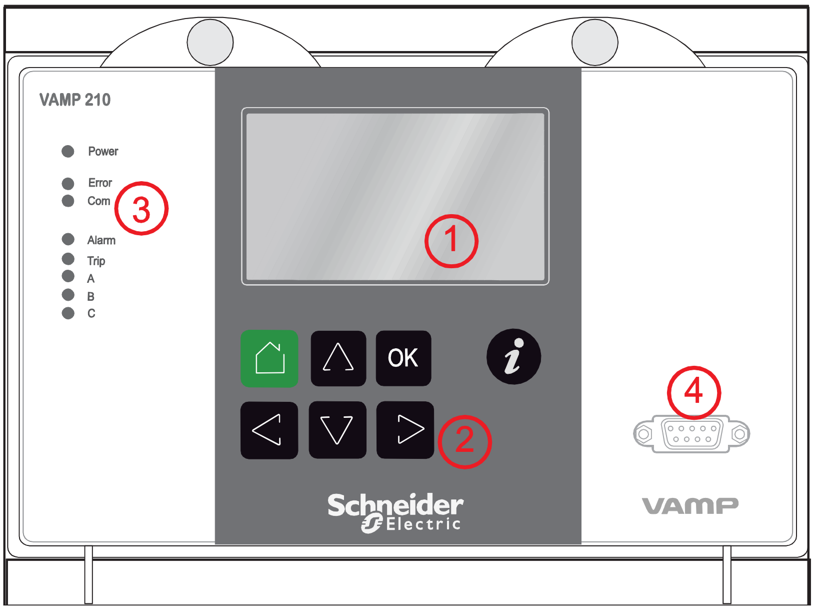


Figure 2.1-1. The front panel of VAMP 210

1. LCD dot matrix display
2. Keypad
3. LED indicators
4. RS 232 serial communication port for PC

2.1.1. Display

The relay is provided with a backlightedt 128x64 LCD dot matrix display. The display enables showing 21 characters in one row and eight rows at the same time. The display has two different purposes: one is to show the single line diagram of the relay with the object status, measurement values, identification etc. (Figure 2.1.1-1). The other purpose is to show the configuration and parameterization values of the relay (Figure 2.1.1-2).

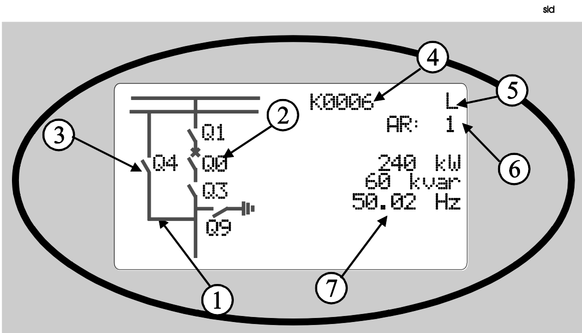


Figure 2.1.1-1 Sections of the LCD dot matrix display

1. Freely configurable single-line diagram
2. Five controllable objects
3. Six object statuses
4. Bay identification
5. Local/Remote selection
6. Auto-reclose on/off selection (if applicable)
7. Freely selectable measurement values (max. six values)

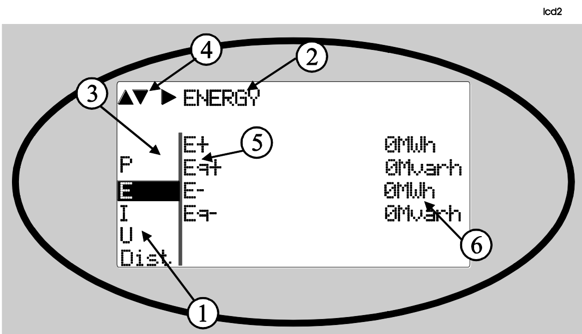


Figure 2.1.1-2 Sections of the LCD dot matrix display

1. Main menu column
2. The heading of the active menu
3. The cursor of the main menu
4. Possible navigating directions (push buttons)
5. Measured/setting parameter
6. Measured/set value

Backlight control

Display backlight can be switched on with a digital input, virtual input or virtual output. LOCALPANEL CONF/**Display backlight ctrl** setting is used for selecting trigger input for backlight control. When the selected input activates (rising edge), display backlight is set on for 60 minutes.

2.1.2. Menu navigation and pointers

1. Use and to move up and down in the main menu, that is, on the left-hand side of the display. The active main menu option is indicated with a cursor. The options in the main menu items are abbreviations, e.g. Evnt = events.
2. After any selection, the arrow symbols in the upper left corner of the display show the possible navigating directions (applicable navigation keys) in the menu.
3. The name of the active submenu and a possible ANSI code of the selected function are shown in the upper part of the display, e.g. CURRENTS.
4. Further, each display holds the measured values and units of one or more quantities or parameters, e.g. ILmax 300A.

2.1.3. Keypad

You can navigate in the menu and set the required parameter values using the keypad and the guidance given in the display. Furthermore, the keypad is used to control objects and switches on the single line diagram display. The keypad is composed of four arrow keys, one cancel key, one enter key and one info key.

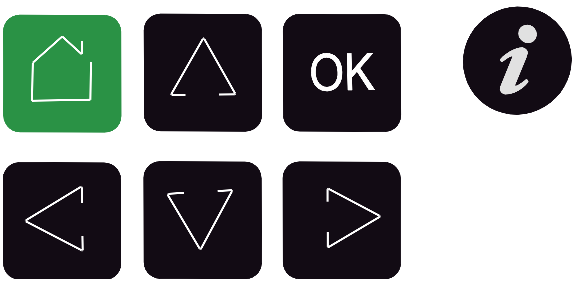


Figure 2.1.3-1 Keys on the keypad

1. Enter and confirmation key (OK)
2. Home / Cancel key ( )
3. Up/Down [Increase/Decrease] arrow keys (/)
4. Keys for selecting submenus [selecting a digit in a numerical value] (/)
5. Additional information key ( )

NOTE! The term, which is used for the buttons in this manual, is inside the brackets.

2.1.4. Operation Indicators

The relay is provided with eight LED indicators:

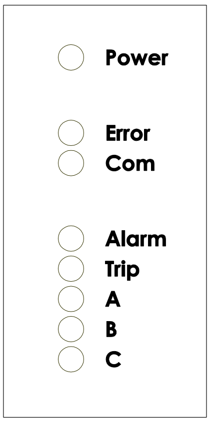


Figure 2.1.4-1. Operation indicators of the relay

LED indicator	Meaning	Measure/ Remarks
Power LED lit	The auxiliary power has been switched on	Normal operation state
Error LED lit	Internal fault, operates in parallel with the self supervision output relay	The relay attempts to reboot [REBOOT]. If the error LED remains lit, call for maintenance.
Com LED lit or flashing	The serial bus is in use and transferring information	Normal operation state
Alarm LED lit	One or several signals of the output relay matrix have been assigned to output LA and the output has been activated by one of the signals. (For more information about output matrix, please see chapter 2.4.5).	The LED is switched off when the signal that caused output Al to activate, e.g. the START signal, is reset. The resetting depends on the type of configuration, connected or latched.
Trip LED lit	One or several signals of the output relay matrix have been assigned to output Tr, and the output has been activated by one of the signals. (For more information about output relay configuration, please see chapter 2.4.5).	The LED is switched off when the signal that caused output Tr to activate, e.g. the TRIP signal, is reset. The resetting depends on the type of configuration, connected or latched.
A- C LED lit	Application-related status indicators.	Configurable

Resetting latched indicators and output relays

All the indicators and output relays can be given a latching function in the configuration.

There are several ways to reset latched indicators and relays:

- From the alarm list, move back to the initial display by pushing  for approx. 3 s. Then reset the latched indicators and output relays by pushing OK.
- Acknowledge each event in the alarm list one by one by pushing OK equivalent times. Then, in the initial display, reset the latched indicators and output relays by pushing OK.

The latched indicators and relays can also be reset via a remote communication bus or via a digital input configured for that purpose.

2.1.5. Adjusting display contrast

The readability of the LCD varies with the brightness and the temperature of the environment. The contrast of the display can be adjusted via the PC user interface, see chapter **3**.

2.2. Local panel operations

The front panel can be used to control objects, change the local/ remote status, read the measured values, set parameters, and to configure relay functions. Some parameters, however, can only be set by means of a PC connected to one of the local communication ports. Some parameters are factory-set.

2.2.1. Navigating in menus

All the menu functions are based on the main menu/submenu structure:

1. Use the arrow keys  and  to move up and down in the main menu.
2. To move to a submenu, repeatedly push  until the required submenu is shown. Correspondingly, push  to return to the main menu.
3. Push  to confirm the selected submenu. If there are more than six items in the selected submenu, a black line appears to the right side of the display (Figure 2.2.1-1). It is then possible to scroll down in the submenu.
4. Push  to cancel a selection.
5. Pushing the  or  key in any position of a sub-menu, when it is not selected, brings you directly one step up or down in the main menu.

The active main menu selection is indicated with black back-ground color. The possible navigating directions in the menu are shown in the upper-left corner by means of black triangular symbols.

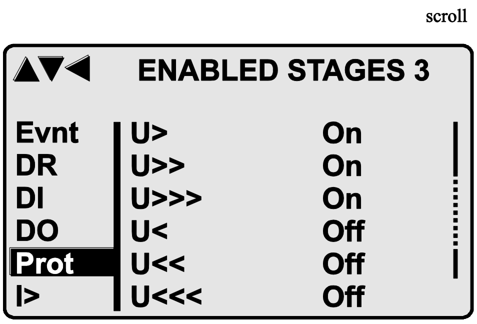


Figure 2.2.1-1. Example of scroll indication

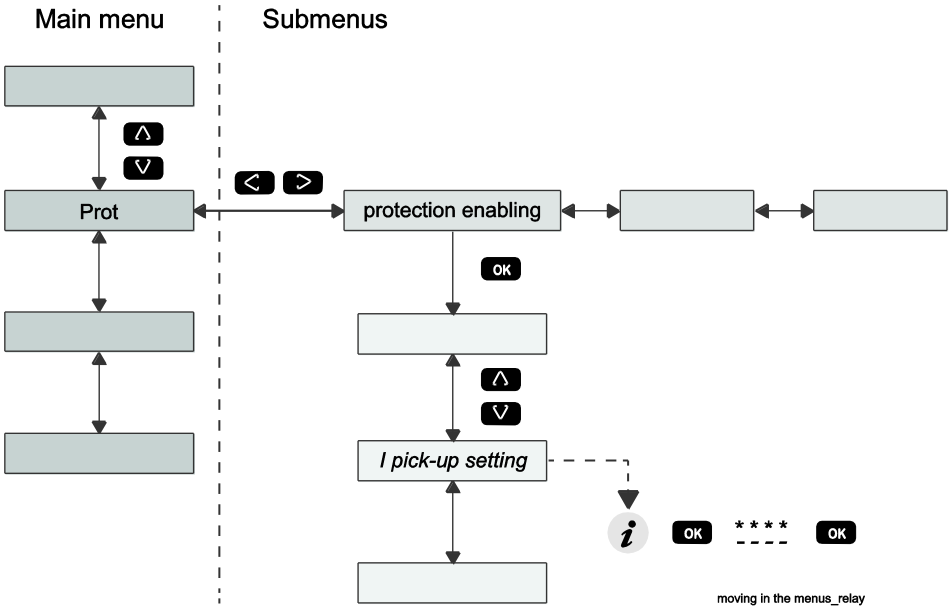


Figure 2.2.1-2. Principles of the menu structure and navigation in the menus

6. Push to obtain additional information about any menu item.
7. Push to revert to the normal display.

Main menu

The general menu structure is shown in Figure 2.2.1-2. The menu is dependent on the user's configuration and the options according the order code. For example only the enabled protection stages will appear in the menu.

A list of the local main menu

Main menu	Number of menus	Description	ANSI code	Note
	1	Interactive mimic display		1
	5	Double size measurements defined by the user		1
	1	Title screen with device name, time and firmware version.		
P	14	Power measurements		
E	4	Energy measurements		
I	13	Current measurements		
U	15	Voltage measurements		
Dema	15	Demand values		
Umax	5	Time stamped min & max of voltages		
Imax	9	Time stamped min & max of currents		
Pmax	5	Time stamped min & max of power and frequency		
Mont	21	Maximum values of the last 31 days and the last twelve months		
Evnt	2	Events		
DR	2	Disturbance recorder		2
Runh	2	Running hour counter. Active time of a selected digital input and time stamps of the latest start and stop.		
TIMR	6	Day and week timers		
DI	5	Digital inputs including virtual inputs		
DO	4	Digital outputs (relays) and output matrix		
ExtAI	3	External analogue inputs		3
ExDI	3	External digital inputs		3
ExDO	3	External digital outputs		3
Prot	27	Protection counters, combined overcurrent status, protection status, protection enabling, cold load and inrush detectionIf2> and block matrix		
I>	5	1st overcurrent stage	50/51	4
I>>	3	2nd overcurrent stage	50/51	4
I>>>	3	3rd overcurrent stage	50/51	4
Iv>	4	Voltage restrained/controlled overcurrent stage	51V	4
Iφ>	6	1st directional overcurrent stage	67	4
Iφ>>	6	2nd directional overcurrent stage	67	4
Iφ>>>	4	3rd directional overcurrent stage	67	4
Iφ>>>>	4	4th directional overcurrent stage	67	4
I<	3	Undercurrent stage	37	4
I2>	3	Current unbalance stage	46	4
T>	3	Thermal overload stage	49	4
Io>	5	1st earth fault stage	50N/51N	4
Io>>	3	2nd earth fault stage	50N/51N	4
Io>>>	3	3rd earth fault stage	50N/51N	4
Io>>>>	3	4th earth fault stage	50N/51N	4

Main menu	Number of menus	Description	ANSI code	Note
Ioφ>	6	1st directional earth fault stage	67N	4
Ioφ>>	6	2nd directional earth fault stage	67N	4
Ioint>	4	Transient intermittent E/F	67NI	4
U>	4	1st overvoltage stage	59	4
U>>	3	2nd overvoltage stage	59	4
U>>>	3	3rd overvoltage stage	59	4
Uf>	3	Overexcitation stage volt/hertz	24	4
U<	4	1st undervoltage stage	27	4
U<<	3	2nd undervoltage stage	27	4
U<<<	3	3rd undervoltage stage	27	4
U1<	4	1st positive sequence undervoltage stage	27P	4
U1<<	4	2nd positive sequence undervoltage stage	27P	4
Uo>	3	1st residual overvoltage stage	59N	4
Uo>>	3	2nd residual overvoltage stage	59N	4
Uof3<	3	100% stator earth fault stage	64F3	4
P<	3	1st reverse and underpower stage	32	4
P<<	3	2nd reverse and underpower stage	32	4
Q<	5	Under excitation stage	40	4
Z<	3	1st underimpedance stage	21	4
Z<<	3	2nd underimpedance stage	21	4
X<	3	1st loss of excitation stage	40/21	4
X<<	3	2nd loss of excitation stage	40/21	4
f><	4	1st over/under-frequency stage	81	4
f>><<	4	2nd over/under-frequency stage	81	4
f<	4	1st underfrequency stage	81L	4
f<<	4	2nd underfrequency stage	81L	4
dfdt	3	Rate of change of frequency (ROCOF) stage	81R	4
Prg1	3	1st programmable stage		4
Prg2	3	2nd programmable stage		4
Prg3	3	3rd programmable stage		4
Prg4	3	4th programmable stage		4
Prg5	3	5th programmable stage		4
Prg6	3	6th programmable stage		4
Prg7	3	7th programmable stage		4
Prg8	3	8th programmable stage		4
If2>	3	Second harmonic O/C stage	51F2	4
CBFP	3	Circuit breaker failure protection	50BF	4
CBWE	4	Circuit breaker wearing supervision		4
CTSV	1	CT supervisor		4
VTSV	1	VT supervisor		4
ArcI>	4	Optional arc protection stage for phase-to-phase faults and delayed light signal.	50ARC	4
ArcIo>	3	Optional arc protection stage for earth faults. Current input = I01	50NARC	4
ArcIo2>	3	Optional arc protection stage for earth faults. Current input = I02	50NARC	4
OBJ	11	Object definitions		5

Main menu	Number of menus	Description	ANSI code	Note
Lgic	2	Status and counters of user's logic		1
CONF	10+2	Device setup, scaling etc.		6
Bus	13	Serial port and protocol configuration		7
Diag	6	Device selfdiagnosis		

Notes

1. Configuration is done with VAMPSET
2. Recording files are read with VAMPSET
3. The menu is visible only if protocol "ExternalIO" is selected for one of the serial ports. Serial ports are configured in menu "Bus".
4. The menu is visible only if the stage is enabled.
5. Objects are circuit breakers, disconnectors etc.. Their position or status can be displayed and controlled in the interactive mimic display.
6. There are two extra menus, which are visible only if the access level "operator" or "configurator" has been opened with the corresponding password.
7. Detailed protocol configuration is done with VAMPSET.

2.2.2. Menu structure of protection functions

The general structure of all protection function menus is similar although the details do differ from stage to stage. As an example the details of the second overcurrent stage I>> menus are shown below.

First menu of I>> 50/51 stage

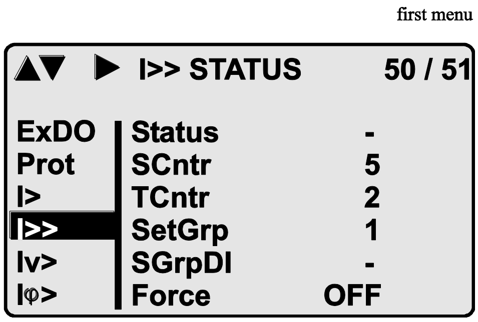


Figure 2.2.2-1 First menu of I>> 50/51 stage

This is the status, start and trip counter and setting group menu. The content is:

- Status –

  The stage is not detecting any fault at the moment. The stage can also be forced to pick-up or trip if the operating level is "Configurator" and the force flag below is on. Operating levels are explained in chapter 2.2.5.

- SCntr 5

  The stage has picked-up a fault five times since the last reset of restart. This value can be cleared if the operating level is at least "Operator".

- TCntr 1

  The stage has tripped two times since the last reset of restart. This value can be cleared if the operating level is at least "Operator".

- SetGrp 1

  The active setting group is one. This value can be edited if the operating level is at least "Operator". Setting groups are explained in chapter 2.2.3.

- SGrpDI -

  The setting group is not controlled by any digital input. This value can be edited if the operating level is at least "Configurator".

- Force Off

  The status forcing and output relay forcing is disabled. This force flag status can be set to "On" or back to "Off" if the operating level is at least "Configurator". If no front panel

button is pressed within five minutes and there is no VAMPSET communication, the force flag will be set to "Off" position. The forcing is explained in chapter 2.3.4.

Second menu of I>> 50/51 stage

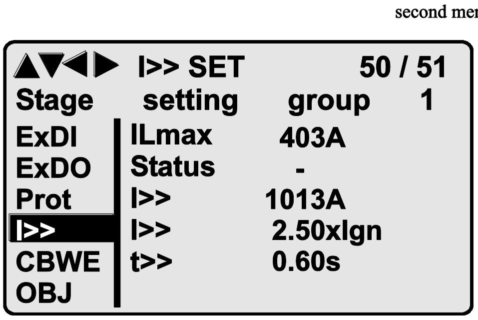


Figure 2.2.2-2. Second menu (next on the right) of I>> 50/51 stage

This is the main setting menu. The content is:

- Stage setting group 1

  These are the group 1 setting values. The other setting group can be seen by pressing push OK and then > or <. Setting groups are explained in chapter 2.2.3.

- ILmax 403A

  The maximum of the three measured phase currents is at the moment 403 A. This is the value the stage is supervising.

- Status –

  Status of the stage. This is just a copy of the status value in the first menu.

- I>> 1013 A

  The pick-up limit is 1013 A in primary value.

- I>> 2.50xIgn

  The pick-up limit is 2.50 times the rated current of the generator. This value can be edited if the operating level is at least "Operator". Operating levels are explained in chapter 2.2.5.

- t>> 0.60s

  The total operation delay is set to 600 ms. This value can be edited if the operating level is at least "Operator".

Third menu of I>> 50/51 stage

third menu

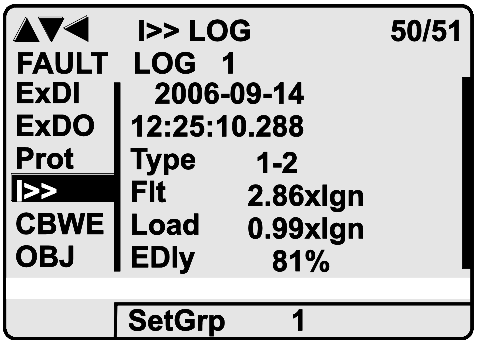


Figure 2.2.2-3. Third and last menu (next on the right) of I>> 50/51 stage

This is the menu for registered values by the I>> stage. Fault logs are explained in chapter 2.2.4.

- FAULT LOG 1
  This is the latest of the eight available logs. You may move between the logs by pressing push OK and then > or <.
- 2006-09-14
  Date of the log.
- 12:25:10.288
  Time of the log.
- Type 1-2
  The overcurrent fault has been detected in phases L1 and L2 (A & B, red & yellow, R&S, u&v).
- Flt 2.86xIgn
  The fault current has been 2.86 per unit.
- Load 0.99xIgn
  The average load current before the fault has been 0.99 pu.
- EDly 81%
  The elapsed operation delay has been 81% of the setting 0.60 s = 0.49 s. Any registered elapsed delay less than 100 % means that the stage has not tripped, because the fault duration has been shorter than the delay setting.
- SetGrp 1
  The setting group has been 1. This line can be reached by pressing OK and several times ▽.

2.2.3. Setting groups

Most of the protection functions of the relay have two setting groups. These groups are useful for example when the network topology is changed frequently. The active group can be changed by a digital input, through remote communication or locally by using the local panel.

The active setting group of each protection function can be selected separately. Figure 2.2.3-1 shows an example where the changing of the I> setting group is handled with digital input one (SGrpDI). If the digital input is TRUE, the active setting group is group two and correspondingly, the active group is group one, if the digital input is FALSE. If no digital input is selected (SGrpDI = -), the active group can be selected by changing the value of the parameter SetGrp.

group1

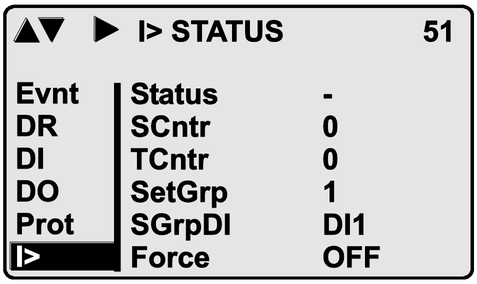


Figure 2.2.3-1. Example of protection submenu with setting group parameters

The changing of the setting parameters can be done easily. When the desired submenu has been found (with the arrow keys), press OK to select the submenu. Now the selected setting group is indicated in the down-left corner of the display (See Figure 2.2.3-2). Set1 is setting group one and Set2 is setting group two. When the needed changes, to the selected setting group, have been done, press < or > to select another group (< is used when the active setting group is 2 and > is used when the active setting group is 1).

group2

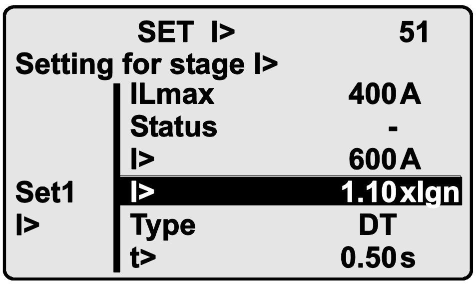


Figure 2.2.3-2. Example of I> setting submenu

2.2.4. Fault logs

All the protection functions include fault logs. The fault log of a function can register up to eight different faults with time stamp information, fault values etc. Each function has its own logs (See Figure 2.2.4-1).

log1

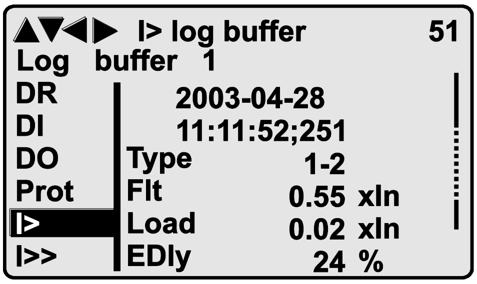


Figure 2.2.4-1. Example of fault log

To see the values of, for example, log two, press OK to select the current log (log one). The current log number is then indicated in the down-left corner of the display (See Figure 2.2.4-2, Log2 = log two). The log two is selected by pressing > once.

log2

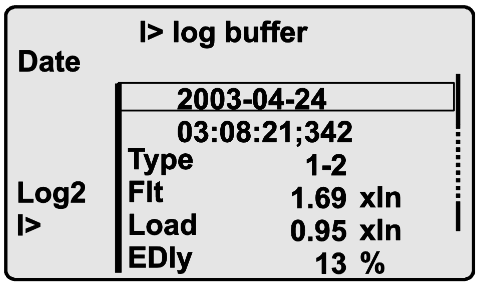


Figure 2.2.4-2. Example of selected fault log

2.2.5. Operating levels

The relay has three operating levels: **User level**, **Operator level** and **Configurator level**. The purpose of the access levels is to prevent accidental change of relay configurations, parameters or settings.

USER level

Use:	Possible to read e.g. parameter values, measurements and events
Opening:	Level permanently open
Closing:	Closing not possible

OPERATOR level

Use:	Possible to control objects and to change e.g. the settings of the protection stages
Opening:	Default password is 1
Setting state:	Push OK
Closing:	The level is automatically closed after 10 minutes idle time. Giving the password 9999 can also close the level.

CONFIGURATOR level

Use:	The configurator level is needed during the commissioning of the relay. E.g. the scaling of the voltage and current transformers can be set.
Opening:	Default password is 2
Setting state:	Push OK
Closing:	The level is automatically closed after 10 minutes idle time. Giving the password 9999 can also close the level.

Opening access

1. Push i and OK on the front panel.

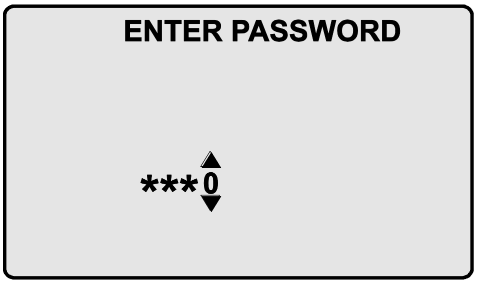


Figure 2.2.5-1. Opening the access level

2. Enter the password needed for the desired level: the password can contain four digits. The digits are supplied one by one by first moving to the position of the digit using > and then setting the desired digit value using ∧.
3. Push OK.

Password handling

The passwords can only be changed using VAMPSET software connected to the local RS-232 port on the relay.

It is possible to restore the password(s) in case the password is lost or forgotten. In order to restore the password(s), a relay program is needed. The serial port settings are 38400 bps, 8 data bits, no parity and one stop bit. The bit rate is configurable via the front panel.

Command	Description
get pwd_break	Get the break code (Example: 6569403)
get serno	Get the serial number of the relay (Example: 12345)

Send both the numbers to your nearest Schneider Electric Customer Care Centre and ask for a password break. A device specific break code is sent back to you. That code will be valid for the next two weeks.

Command	Description
set pwd_break=4435876	Restore the factory default passwords (“4435876” is just an example. The actual code should be asked from your nearest Schneider Electric Customer Care Centre.)

Now the passwords are restored to the default values (See chapter 2.2.5).

2.3. Operating measures

2.3.1. Control functions

The default display of the local panel is a single-line diagram including relay identification, Local/Remote indication, Auto-reclose on/off selection and selected analogue measurement values.

Please note that the operator password must be active in order to be able to control the objects. Please refer to page 26 Opening access.

Toggling Local/Remote control

1. Push **OK**. The previously activated object starts to blink.
2. Select the Local/Remote object (“L” or “R” squared) by using the arrow keys.
3. Push **OK**. The L/R dialog opens. Select “REMOTE” to enable remote control and disable local control. Select “LOCAL” to enable local control and disable remote control.
4. Confirm the setting by pushing **OK**. The Local/Remote state will change.

Object control

1. Push **OK**. The previously activated object starts to blink.
2. Select the object to control by using the arrow keys. Please note that only controllable objects can be selected.
3. Push **OK**. A control dialog opens.
4. Select the “Open” or “Close” command by using ∧ and ∨.
5. Confirm the operation by pushing **OK**. The state of the object changes.

Toggling virtual inputs

1. Push **OK**. The previously activated object starts to blink.
2. Select the virtual input object (empty or black square)
3. The dialog opens
4. Select “VIon” to activate the virtual input or select “VIoff” to deactivate the virtual input

2.3.2. Measured data

The measured values can be read from the P, E, I and U menus and their submenus. Furthermore, any measurement value in the following table can be displayed on the main view next to the single line diagram. Up to six measurements can be shown.

Value	Menu/Submenu	Description
P	P/POWER	Active power [kW]
Q	P/POWER	Reactive power [kvar]
S	P/POWER	Apparent power [kVA]
φ	P/POWER	Active power angle [°]
P.F.	P/POWER	Power factor
f	P/POWER	Frequency [Hz]
Pda	P/15 MIN POWER	Active power [kW]
Qda	P/15 MIN POWER	Reactive power [kvar]
Sda	P/15 MIN POWER	Apparent power [kVA]
Pfda	P/15 MIN POWER	Power factor
fda	P/15 MIN POWER	Frequency [Hz]
PL1	P/POWER/PHASE 1	Active power of phase 1 [kW]
PL2	P/POWER/PHASE 1	Active power of phase 2 [kW]
PL3	P/POWER/PHASE 1	Active power of phase 3 [kW]
QL1	P/POWER/PHASE 1	Reactive power of phase 1 [kvar]
QL2	P/POWER/PHASE 1	Reactive power of phase 2 [kvar]
QL3	P/POWER/PHASE 1	Reactive power of phase 3 [kvar]
SL1	P/POWER/PHASE 2	Apparent power of phase 1 [kVA]
SL2	P/POWER/PHASE 2	Apparent power of phase 2 [kVA]
SL3	P/POWER/PHASE 2	Apparent power of phase 3 [kVA]
PF_L1	P/POWER/PHASE 2	Power factor of phase 1
PF_L2	P/POWER/PHASE 2	Power factor of phase 2
PF_L3	P/POWER/PHASE 2	Power factor of phase 3
cos	P/COS & TAN	Cosine phi
tan	P/COS & TAN	Tangent phi
cosL1	P/COS & TAN	Cosine phi of phase L1
cosL2	P/COS & TAN	Cosine phi of phase L2
cosL3	P/COS & TAN	Cosine phi of phase L3
Iseq	P/PHASE SEQUENCIES	Actual current phase sequency [OK; Reverse; ??]
Useq	P/PHASE SEQUENCIES	Actual voltage phase sequency [OK; Reverse; ??]
Ioφ	P/PHASE SEQUENCIES	Io/Uo angle [°]
Io2φ	P/PHASE SEQUENCIES	Io2/Uo angle [°]
fAdop	P/PHASE SEQUENCIES	Adapted network frequency [Hz]
E+	E/ENERGY	Exported energy [MWh]
Eq+	E/ENERGY	Exported reactive energy [Mvar]
E-	E/ENERGY	Imported energy [MWh]
Eq-	E/ENERGY	Imported reactive energy [Mvar]
E+.nn	E/DECIMAL COUNT	Decimals of exported energy

Value	Menu/Submenu	Description
Eq.nn	E/DECIMAL COUNT	Decimals of reactive energy
E-.nn	E/DECIMAL COUNT	Decimals of imported energy
Ewrap	E/DECIMAL COUNT	Maximum energy counter value
E+	E/E-PULSE SIZES	Pulse size of exported energy [kWh]
Eq+	E/E-PULSE SIZES	Pulse size of exported reactive energy [kvar]
E-	E/E-PULSE SIZES	Pulse size of imported energy [kWh]
Eq-	E/E-PULSE SIZES	Pulse duration of imported reactive energy [ms]
E+	E/E-PULSE DURATION	Pulse duration of exported energy [ms]
Eq+	E/E-PULSE DURATION	Pulse duration of exported reactive energy [ms]
E-	E/E-PULSE DURATION	Pulse duration of imported energy [ms]
Eq-	E/E-PULSE DURATION	Pulse duration of imported reactive energy [ms]
E+	E/E-pulse TEST	Test the exported energy pulse
Eq+	E/E-pulse TEST	Test the exported reactive energy pulse
E-	E/E-pulse TEST	Test the imported energy pulse
Eq-	E/E-pulse TEST	Test the imported reactive energy pulse
IL1	I/PHASE CURRENTS	Phase current IL1 [A]
IL2	I/PHASE CURRENTS	Phase current IL2 [A]
IL3	I/PHASE CURRENTS	Phase current IL3 [A]
IL1da	I/PHASE CURRENTS	15 min average for IL1 [A]
IL2da	I/PHASE CURRENTS	15 min average for IL2 [A]
IL3da	I/PHASE CURRENTS	15 min average for IL3 [A]
Io	I/SYMMETRIC CURRENTS	Primary value of zerosequence/ residual current Io [A]
Io2	I/SYMMETRIC CURRENTS	Primary value of zero-sequence/residual current Io2 [A]
IoC	I/SYMMETRIC CURRENTS	Calculated Io [A]
I1	I/SYMMETRIC CURRENTS	Positive sequence current [A]
I2	I/SYMMETRIC CURRENTS	Negative sequence current [A]
I2/I1	I/SYMMETRIC CURRENTS	Negative sequence current related to positive sequence current (for unbalance protection) [%]
THDIL	I/HARM. DISTORTION	Total harmonic distortion of the mean value of phase currents [%]
THDIL1	I/HARM. DISTORTION	Total harmonic distortion of phase current IL1 [%]
THDIL2	I/HARM. DISTORTION	Total harmonic distortion of phase current IL2 [%]
THDIL3	I/HARM. DISTORTION	Total harmonic distortion of phase current IL3 [%]
Diagram	I/HARMONICS of IL1	Harmonics of phase current IL1 [%] (see Figure 2.3.2-1)
Diagram	I/HARMONICS of IL2	Harmonics of phase current IL2 [%] (see Figure 2.3.2-1)

Value	Menu/Submenu	Description
Diagram	I/HARMONICS of IL3	Harmonics of phase current IL3 [%] (see Figure 2.3.2-1)
Uline	U/LINE VOLTAGES	Average value for the three line voltages [V]
U12	U/LINE VOLTAGES	Phase-to-phase voltage U12 [V]
U23	U/LINE VOLTAGES	Phase-to-phase voltage U23 [V]
U31	U/LINE VOLTAGES	Phase-to-phase voltage U31 [V]
UL	U(PHASE VOLTAGES	Average for the three phase voltages [V]
UL1	U/PHASE VOLTAGES	Phase-to-earth voltage UL1 [V]
UL2	U/PHASE VOLTAGES	Phase-to-earth voltage UL2 [V]
UL3	U/PHASE VOLTAGES	Phase-to-earth voltage UL3 [V]
Uo	U/SYMMETRIC VOLTAGES	Residual voltage Uo [%]
U1	U/SYMMETRIC VOLTAGES	Positive sequence voltage [%]
U2	U/SYMMETRIC VOLTAGES	Negative sequence voltage [%]
U2/U1	U/SYMMETRIC VOLTAGES	Negative sequence voltage related to positive sequence voltage [%]
THDU	U/HARM. DISTORTION	Total harmonic distortion of the mean value of voltages [%]
THDUa	U/HARM. DISTORTION	Total harmonic distortion of the voltage input a [%]
THDUb	U/HARM. DISTORTION	Total harmonic distortion of the voltage input b [%]
THDUc	U/HARM. DISTORTION	Total harmonic distortion of the voltage input c [%]
Diagram	U/HARMONICS of input Ua	Harmonics of voltage input Ua [%] (see Figure 2.3.2-1)
Diagram	U/HARMONICS of input Ub	Harmonics of voltage input Ub [%] (see Figure 2.3.2-1)
Diagram	U/HARMONICS of input Uc	Harmonics of voltage input Uc [%] (see Figure 2.3.2-1)
Count	U/VOLT. INTERRUPTS	Voltage interrupt counter
Prev	U/VOLT. INTERRUPTS	Previous interruption
Total	U/VOLT. INTERRUPTS	Total duration of voltage interruptions [days, hours]
Prev	U/VOLT. INTERRUPTS	Duration of previous interruption
Status	U/VOLT. INTERRUPTS	Voltage status [LOW; NORMAL]

harm

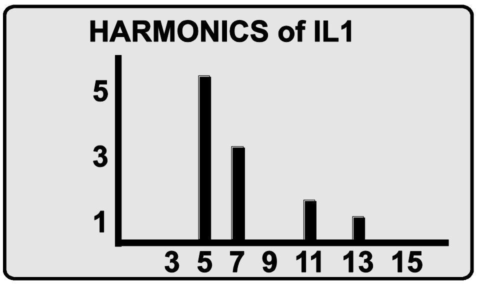


Figure 2.3.2-1. Example of harmonics bar display

2.3.3. Reading event register

The event register can be read from the Evnt submenu:

1. Push > once.
2. The EVENT LIST appears. The display contains a list of all the events that have been configured to be included in the event register.

event_list

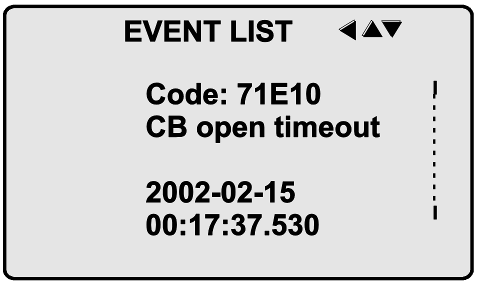


Figure 2.3.3-1. Example of an event register

3. Scroll through the event list with ∧ and ∨.
4. Exit the event list by pushing <.

It is possible to set the order in which the events are sorted. If the “Order” -parameter is set to “New-Old”, then the first event in the EVENT LIST is the most recent event.

2.3.4. Forced control (Force)

In some menus it is possible to switch a signal on and off by using a force function. This feature can be used, for instance, for testing a certain function. The force function can be activated as follows:

1. Move to the setting state of the desired function, for example DO (see Chapter 2.4, on page 33).
2. Select the Force function (the background color of the force text is black).

VAMP 210 force

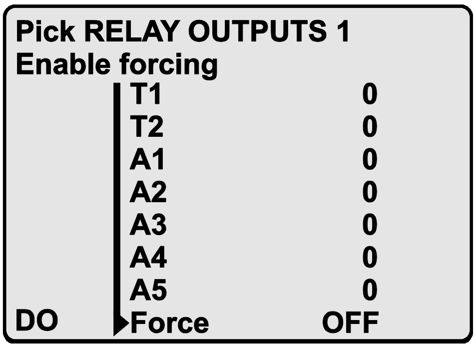


Figure 2.3.4-1. Selecting Force function

3. Push OK.
4. Push ∧ or ∨ to change the "OFF" text to "ON", that is, to activate the Force function.
5. Push OK to return to the selection list. Choose the signal to be controlled by force with ∧ and ∨, for instance the T1 signal.
6. Push OK to confirm the selection. Signal T1 can now be controlled by force.
7. Push ∧ or ∨ to change the selection from "0" (not alert) to "1" (alert) or vice versa.
8. Push OK to execute the forced control operation of the selected function, e.g., making the output relay of T1 to pick up.
9. Repeat the steps 7 and 8 to alternate between the on and off state of the function.
10. Repeat the steps 1...4 to exit the Force function.
11. Push ⌂ to return to the main menu.

NOTE! All the interlockings and blockings are bypassed when the force control is used.

2.4. Configuration and parameter setting

The minimum procedure to configure a relay is

1. Open the access level "Configurator". The default password for configurator access level is 2.
2. Set the rated values in menu [CONF] including at least current transformers, voltage transformers and generator ratings. Also the date and time settings are in this same main menu.
3. Enable the needed protection functions and disable the rest of the protection functions in main menu [Prot].
4. Set the setting parameter of the enable protection stages according the application.
5. Connect the output relays to the start and trip signals of the enabled protection stages using the output matrix. This can be done in main menu [DO], although the VAMPSET program is recommended for output matrix editing.
6. Configure the needed digital inputs in main menu [DI].
7. Configure blocking and interlockings for protection stages using the block matrix. This can be done in main menu [Prot], although VAMPSET is recommended for block matrix editing.

Some of the parameters can only be changed via the RS-232 serial port using the VAMPSET software. Such parameters, (for example passwords, blockings and mimic configuration) are normally set only during commissioning.

Some of the parameters require the restarting of the relay. This restarting is done automatically when necessary. If a parameter change requires restarting, the display will show as Figure 2.4-1.

autoboot

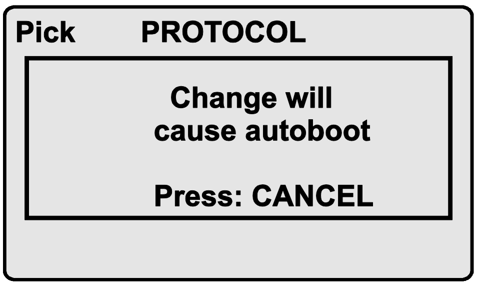


Figure 2.4-1 Example of auto-reset display

Press  to return to the setting view. If a parameter must be changed, press OK again. The parameter can now be set. When the parameter change is confirmed with OK, a [RESTART]- text appears to the top-right corner of the display. This means that auto-resetting is pending. If no key is pressed, the auto-reset will be executed within few seconds.

2.4.1. Parameter setting

1. Move to the setting state of the desired menu (for example CONF/CURRENT SCALING) by pushing OK. The Pick text appears in the upper-left part of the display.
2. Enter the password associated with the configuration level by pushing i and then using the arrow keys and OK (default value is 0002). For more information about the access levels, please refer to Chapter 2.2.5.
3. Scroll through the parameters using ∧ and ∨. A parameter can be set if the background color of the line is black. If the parameter cannot be set the parameter is framed.
4. Select the desired parameter (for example Inom) with OK.
5. Use the ∧ and ∨ to change a parameter value. If the value contains more than one digit, use < and > to shift from digit to digit, and the ∧ and ∨ to change the digits.
6. Push OK to accept a new value. If you want to leave the parameter value unchanged, exit the edit state by pushing ⌂.

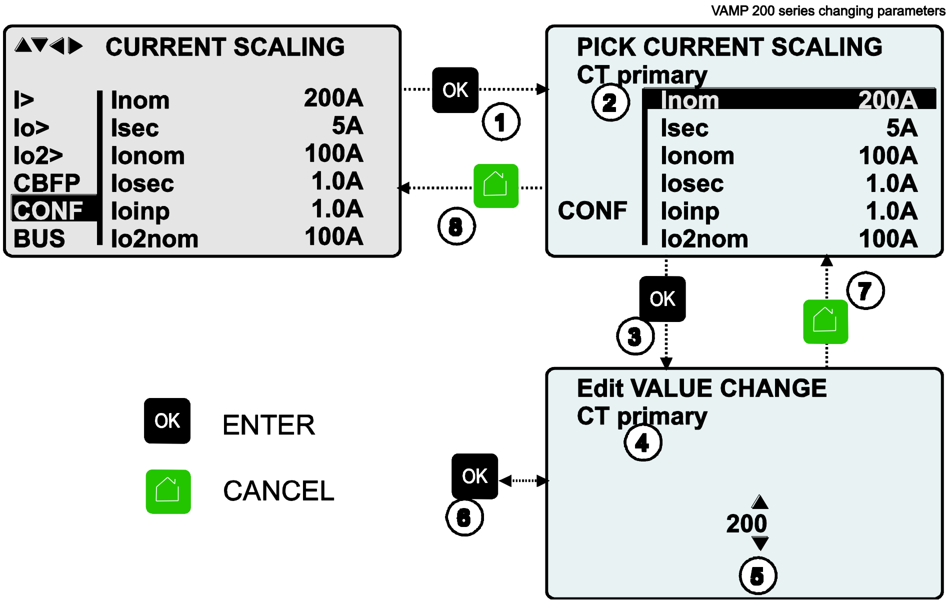


Figure 2.4.1-1.Changing parameters

2.4.2. Setting range limits

If the given parameter setting values are out-of-range values, a fault message will be shown when the setting is confirmed with OK. Adjust the setting to be within the allowed range.

illegal

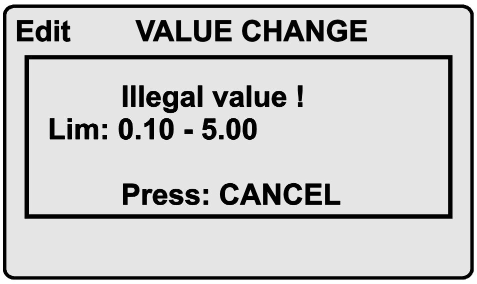


Figure 2.4.2-1 Example of a fault message

The allowed setting range is shown in the display in the setting mode. To view the range, push *i*. Push to return to the setting mode.

infoset_I

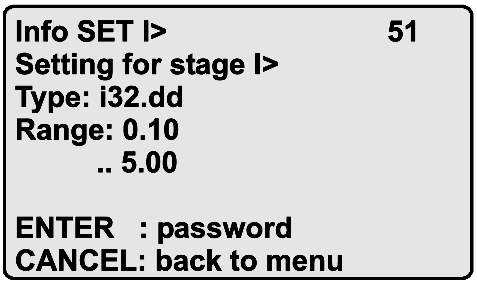


Figure 2.4.2-2. Allowed setting ranges show in the display

2.4.3. Disturbance recorder menu DR

Via the submenus of the disturbance recorder menu the following functions and features can be read and set:

DISTURBANCE RECORDER

- Recording mode (Mode)
- Sample rate (Rate)
- Recording time (Time)
- Pre trig time (PreTrig)
- Manual trigger (MnlTrig)
- Count of ready records (ReadyRe)

REC. COUPLING

- Add a link to the recorder (AddLink)
- Clear all links (ClrLnks)

Available links:

- DO, DI
- Uline, Uphase
- IL
- U2/U1, U2, U1
- I2/In, I2/I1, I2, I1, IoCalc
- CosFii
- PF, S, Q, P
- f
- Uo
- UL3, UL2, UL1
- U31, U23, U12
- Io2, Io
- IL3, IL2, IL1
- Prms, Qrms, Srms
- Tanfii
- THDIL1, THDIL2, THDIL3
- THDUa, THDUb, THDUc
- fy, fz, U12y, U12z

2.4.4. Configuring digital inputs DI

The following functions can be read and set via the submenus of the digital inputs menu:

- The status of digital inputs (DIGITAL INPUTS 1-6/18)
- Operation counters (DI COUNTERS)
- Operation delay (DELAYs for DigIn)
- The polarity of the input signal (INPUT POLARITY). Either normally open (NO) or normally closed (NC) circuit.
- Event enabling EVENT MASK1

2.4.5. Configuring digital outputs DO

The following functions can be read and set via the submenus of the digital outputs menu:

- The status of the output relays (RELAY OUTPUTS1 and 2)
- The forcing of the output relays (RELAY OUTPUTS1 and 2) (only if Force = ON):
    - Forced control (0 or 1) of the Trip relays
    - Forced control (0 or 1) of the Alarm relays
    - Forced control (0 or 1) of the IF relay
- The configuration of the output signals to the output relays. The configuration of the operation indicators (LED) Alarm and Trip and application specific alarm leds A, B and C (that is, the output relay matrix).

NOTE! The amount of Trip and Alarm relays depends on the relay type and optional hardware.

2.4.6. Protection menu Prot

The following functions can be read and set via the submenus of the Prot menu:

- Reset all the counters (PROTECTION SET/ClAll)
- Read the status of all the protection functions (PROTECT STATUS 1-x)
- Enable and disable protection functions (ENABLED STAGES 1-x)
- Define the interlockings between signals (only with VAMPSET).

Each stage of the protection functions can be disabled or enabled individually in the Prot menu. When a stage is enabled, it will be in operation immediately without a need to reset the relay.

The relay includes several protection functions. However, the processor capacity limits the number of protection functions that can be active at the same time.

2.4.7. Configuration menu CONF

The following functions and features can be read and set via the submenus of the configuration menu:

DEVICE SETUP

- Bit rate for the command line interface in ports X4 and the front panel. The front panel is always using this setting. If SPABUS is selected for the rear panel local port X4, the bit rate is according SPABUS settings.
- Access level [Acc]

LANGUAGE

- List of available languages in the relay

CURRENT SCALING

- Rated phase CT primary current (Inom)
- Rated phase CT secondary current (Isec)
- Rated input of the relay [Iinput]. 5 A or 1 A. This is specified in the order code of the device.
- Rated value of I0 CT primary current (Ionom)
- Rated value of I0 CT secondary current (Iosec)
- Rated I01 input of the relay [Ioinp]. 5 A or 1 A. This is specified in the order code of the device.
- Rated value of I02 CT primary current (Io2nom)
- Rated value of I02 CT secondary current (Io2sec)
- Rated I02 input of the relay [Io2inp]. 5A, 1 A or 0.2 A. This is specified in the order code of the device.

The rated input values are usually equal to the rated secondary value of the CT.

The rated CT secondary may be greater than the rated input but the continuous current must be less than four times the rated input. In compensated, high impedance earthed and isolated networks using cable transformer to measure residual current I_0, it is quite usual to use a relay with 1 A or 0.2 A input although the CT is 5 A or 1A. This increases the measurement accuracy.

The rated CT secondary may also be less than the rated input but the measurement accuracy near zero current will decrease.

VOLTAGE SCALING

- Rated VT primary voltage (Uprim)
- Rated VT secondary voltage (Usec)
- Rated U0 VT secondary voltage (Uosec)
- Voltage measuring mode (Umode)

GENERATOR SETTING

- Rated voltage of the generator or motor (Ugn).
- Rated power of the generator or motor (Sgn).
- Rated shaft power of the prime mover (Pm). If this value is not known, set it equal to Sgn. The reverse power and underpower stages do use this value as reference for 1.00 per unit.
- Rated current of the generator calculated by the device (Ign).
- Rated impedance of the generator or motor calculated by the device (Zgn).
- Existence of any unit transformer between VTs and CTs (Trafo). In case the VTs are on the bus side of the transformer and CTs are on the generator side, this parameter is set equal to "On". The generator may have a unit transformer, but if the VTs and CTs are on the same side of this transformer, this parameter is set equal to "Off".
- Connection group of the unit transformer, if any. IEC marking with capital letters Y and D for bus side and small case letters y and d for generator side combined with the dial hour is used. For example Yd11 means a wye-delta transformer where the delta side phase-to-ground voltages are leading 30° the wye side phase-to-ground voltages.
- Rated busbar side voltage of the unit transformer, if any (UnBB).
- Rated generator side voltage of the unit transformer, if any (UnGS).

UNITS FOR MIMIC DISPLAY

- Unit for voltages (V). The choices are V (volt) or kV (kilovolt).
- Scaling for active, reactive and apparent power [Power]. The choices are k for kW, kvar and kVA or M for MW, Mvar and MVA.

DEVICE INFO

- Relay type (Type VAMP 210)
- Serial number (SerN)
- Software version (PrgVer)
- Bootcode version (BootVer)

DATE/TIME SETUP

- Day, month and year (Date)
- Time of day (Time)
- Date format (Style). The choices are "yyyy-mm-dd", "dd.nn.yyyy" and "mm/dd/yyyy".

CLOCK SYNCHRONISATION

- Digital input for minute sync pulse (SyncDI). If any digital input is not used for synchronization, select "−".
- Daylight saving time for NTP synchronization (DST).
- Detected source of synchronization (SyScr).
- Synchronization message counter (MsgCnt).
- Latest synchronization deviation (Dev).

The following parameters are visible only when the access level is higher than "User".

- Offset, i.e. constant error, of the synchronization source (SyOS).
- Auto adjust interval (AAIntv).
- Average drift direction (AvDrft): "Lead" or "lag".
- Average synchronization deviation (FilDev).

2.4.8. Protocol menu Bus

There are three communication ports in the rear panel. In addition there is a connector in the front panel overruling the local port in the rear panel.

REMOTE PORT X5

- Communication protocol for remote port X5 [Protocol].
- Message counter [Msg#]. This can be used to verify that the device is receiving messages.
- Communication error counter [Errors].
- Communication time-out error counter [Tout].
- Information of bit rate/data bits/parity/stop bits.
  This value is not directly editable. Editing is done in the appropriate protocol setting menus.

The counters are useful when testing the communication.

LOCAL PORT X4 (pins 2, 3 and 5)

This port is disabled, if a cable is connected to the front panel connector.

- Communication protocol for the local port X4 [Protocol]. For VAMPSET use "None" or "SPABUS".
- Message counter [Msg#]. This can be used to verify that the device is receiving messages.
- Communication error counter [Errors].
- Communication time-out error counter [Tout].
- Information of bit rate/data bits/parity/stop bits.
  This value is not directly editable. Editing is done in the appropriate protocol setting menus. For VAMPSET and protocol "None" the setting is done in menu CONF/DEVICE SETUP.

PC (LOCAL/SPA BUS)

This is a second menu for local port X4. The VAMPSET communication status is showed.

- Bytes/size of the transmitter buffer [Tx].
- Message counter [Msg#]. This can be used to verify that the device is receiving messages.
- Communication error counter [Errors]
- Communication time-out error counter [Tout].
- Same information as in the previous menu.

EXTENSION PORT X4 (pins 7, 8 and 5)

- Communication protocol for extension port X4 [Protocol].
- Message counter [Msg#]. This can be used to verify that the device is receiving messages.
- Communication error counter [Errors].
- Communication time-out error counter [Tout].
- Information of bit rate/data bits/parity/stop bits.
  This value is not directly editable. Editing is done in the appropriate protocol setting menus.

Ethernet port

These parameters are used by the ethernet interface. For changing the nnn.nnn.nnn.nnn style parameter values, VAMPSET is recommended.

- Ethernet port protocol [Protoc].
- IP Port for protocol [Port]
- IP address [IpAddr].
- Net mask [NetMsk].
- Gateway [Gatew].
- Name server [NameSw].
- Network time protocol (NTP) server [NTPSvr].
- TCP Keep alive interval [KeepAlive]
- MAC address [MAC]
- IP Port for Vampset [VS Port]
- Message counter [Msg#]
- Error counter [Errors]
- Timeout counter [Tout]

MODBUS

- Modbus addres for this slave device [Addr]. This address has to be unique within the system.
- Modbus bit rate [bit/s]. Default is "9600".
- Parity [Parity]. Default is "Even".

For details see the technical description part of the manual.

EXTERNAL I/O protocol

This is a Modbus master protocol to communicate with the extension I/O modules connected to the extension port. Only one instance of this protocol is possible.

- Bit rate [bit/s]. Default is "9600".
- Parity [Parity]. Default is "Even".

For details see the technical description part of the manual.

SPA BUS

Several instances of this protocol are possible.

- SPABUS addres for this device [Addr]. This address has to be unique within the system.
- Bit rate [bit/s]. Default is "9600".
- Event numbering style [Emode]. Default is "Channel".

For details see the technical description part of the manual.

IEC 60870-5-101

- Bit rate [bit/s]. Default is “9600”.
- [Parity].
- Link layer address for this device [LLAddr].
- ASDU address [ALAddr].

For details see the technical description part of the manual.

IEC 60870-5-103

Only one instance of this protocol is possible.

- Address for this device [Addr]. This address has to be unique within the system.
- Bit rate [bit/s]. Default is "9600".
- Minimum measurement response interval [MeasInt].
- ASDU6 response time mode [SyncRe].

For details see the technical description part of the manual.

IEC 103 DISTURBANCE RECORDINGS

For details see the technical description part of the manual.

PROFIBUS

Only one instance of this protocol is possible.

- [Mode]
- Bit rate [bit/s]. Use 2400 bps. This parameter is the bit rate between the main CPU and the Profibus ASIC. The actual Profibus bit rate is automatically set by the Profibus master and can be up to 12 Mbit/s.
- Event numbering style [Emode].
- Size of the Profibus Tx buffer [InBuf].
- Size of the Profibus Rx buffer [OutBuf].
  When configuring the Profibus master system, the length of these buffers are needed. The size of the both buffers is set indirectly when configuring the data items for Profibus.
- Address for this slave device [Addr]. This address has to be unique within the system.
- Profibus converter type [Conv]. If the shown type is a dash “-“, either Profibus protocol has not been selected or the device has not restarted after protocol change or there is a communication problem between the main CPU and the Profibus ASIC.

For details see the technical description part of the manual.

DNP3

Only one instance of this protocol is possible.

- Bit rate [bit/s]. Default is "9600".
- [Parity].
- Addres for this device [SlvAddr]. This address has to be unique within the system.
- Master's addres [MstrAddr].

For further details see the technical description part of the manual.

2.4.9. Single line diagram editing

The single-line diagram is drawn with the VAMPSET software. For more information, please refer to the VAMPSET manual (VVAMPSET/EN M/xxxx).

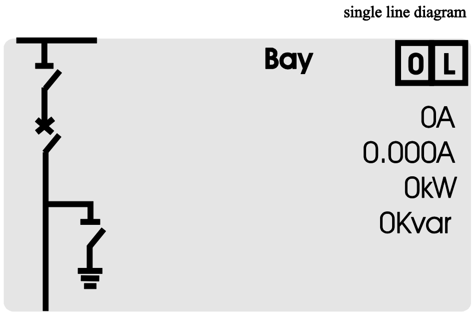


Figure 2.4.9-1. Single line diagram.

2.4.10. Blocking and interlocking configuration

The configuration of the blockings and interlockings is done with the VAMPSET software. Any start or trip signal can be used for blocking the operation of any protection stage. Furthermore, the interlocking between objects can be configured in the same blocking matrix of the VAMPSET software. For more information, please refer to the VAMPSET manual (VVAMPSET/EN M/xxxx).

3. VAMPSET PC software

The PC user interface can be used for:

- On-site parameterization of the relay
- Loading relay software from a computer
- Reading measured values, registered values and events to a computer.
- Continuous monitoring of all values and events.

Two RS 232 serial ports are available for connecting a local PC with VAMPSET to the relay; one on the front panel and one on the rear panel of the relay. These two serial ports are connected in parallel. However, if the connection cables are connected to both ports, only the port on the front panel will be active. To connect a PC to a serial port, use a connection cable of type VX 003-3.

The VAMPSET program can also use TCP/IP LAN connection. Optional hardware is required.

There is a free of charge PC program called VAMPSET available for configuration and setting of VAMP relays. Please download the latest VAMPSET.exe from our web page www.vamp.fi. For more information about the VAMPSET software, please refer to the user's manual with the code VVAMPSET/EN M/xxxx. Also the VAMPSET user's manual is available at our web site.

4. Introduction

The numerical device includes all the essential protection functions needed to protect generators in power plants, industry, offshore applications and embedded power generation.

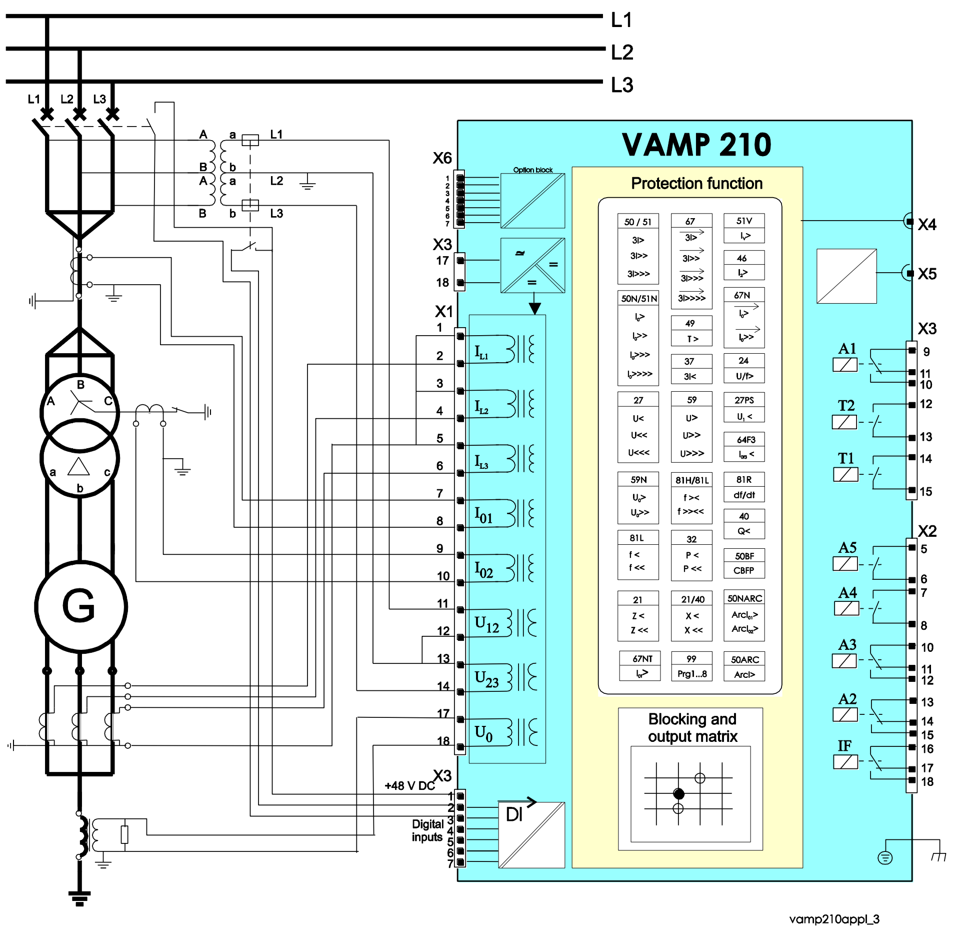


Figure 4-1 Typical application of the VAMP 210 generator protection relay.

4.1. Main features

The main features of VAMP 210 are

- Comprehensive set of protection functions. The protection stages not needed in a particular application can be disabled.
- Versatile measuring functions including currents, voltages, frequency, power, energy, symmetric components, average values etc.
- Control functions and status display for circuit breakers, disconnectors etc.
- Arc protection is available as option.
- Fully digital signal handling with a powerful 16-bit microprocessor, and high measuring accuracy on all the setting ranges due to an accurate 16-bit A/D conversion technique and up to 20-bit dynamic range.
- Easy adaptability of the relay to the power plant automation system or SCADA systems using the wide range of available communication protocols.
- Easy adaptation to traditional alarm systems using the available signal relay outputs and the flexible signal-grouping matrix of the relay.
- Flexible control and blocking possibilities due to digital signal control inputs (DI) and outputs (DO).
- Freely configurable mimic display with busbar, CB etc. symbols and six selectable measurement values.
- Five freely configurable double character size measurement displays.
- Freely programmable interlocking schemes with basic logic functions and timers.
- Recording of time stamped events and fault values.
- Built-in disturbance recorder for evaluating all the analogue and digital signals.
- Disturbance recorder for evaluating all the analogue and digital signals.
- Easy configuration, parameterisation and reading of information via the local human man interface (HMI), or with the free of charge VAMPSET PC program.
- Built-in, self-regulating AC/DC converter for auxiliary power supply from any source within the range from 40 to 265 VDC or VAC . The alternative power supply is for 18 to 36 VDC.

4.2. Principles of numerical protection techniques

The manager is using numerical technology. This means that all the signal filtering, protection and control functions are implemented through digital processing.

The numerical technique used in the manager is primarily based on an adapted Fast Fourier Transformation (FFT) algorithm. Synchronized sampling of the measured voltage and current signals is used. The sample rate is 32 samples/cycle within the frequency range 45 Hz ... 65 Hz. The frequency is measured from the voltage signals and used to synchronize the sampling rate. Therefore secondary testing of a brand new device should be started with voltage protection functions and voltage injection to let the relay learn the local frequency. The learned frequency is used for sampling rate synchronization when no voltage is present. The local network frequency can also be manually given for the relay.

Apart from the FFT calculations, some protection functions also require the symmetrical components to be calculated for obtaining the positive, negative and zero phase sequence components of the measured quantity. For example, the function of the unbalanced load protection stage is based on the use of the negative phase sequence component of the current.

Figure 4.2-1 shows a hardware block diagram of the relay. The main components are the current and voltage inputs, digital input elements, output relays, A/D converters and the microcomputer and a power supply unit.

Figure 4.2-2 shows the inputs and outputs of a general protection function. The FFT block is calculating the fundamental frequency phasors and also harmonics used by some protection functions. The block matrix is used for simple interlocking. (More complex interlocking is done with the user's programmable logic). The output matrix is used to connect the pick-up and trip signals from protection blocks to the output relays and indicators.

Figure 4.2-3 shows a block diagram of a basic overcurrent or overvoltage function with definite and inverse operation time.

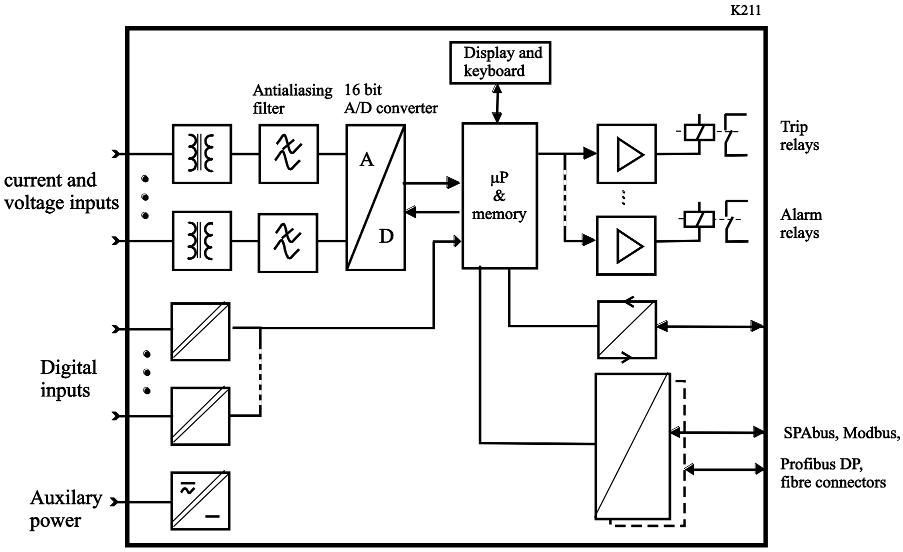


Figure 4.2-1 Principle block diagram of the hardware.

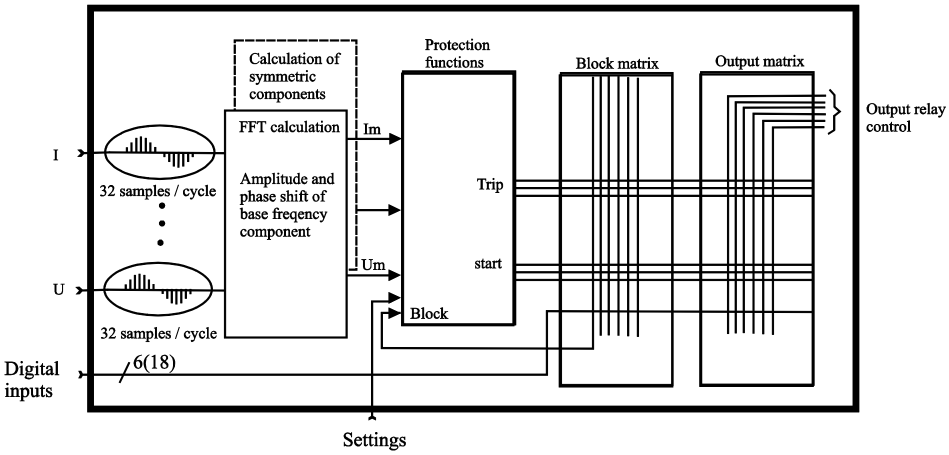


Figure 4.2-2 Block diagram of signal processing and protection software.

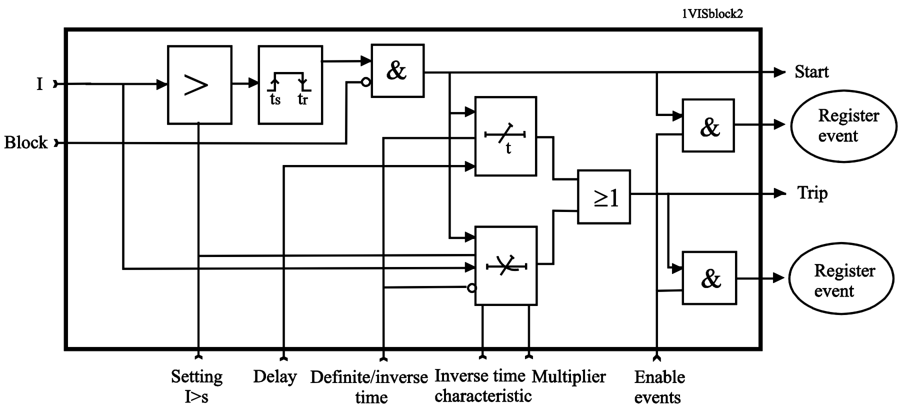


Figure 4.2-3 Block diagram of a basic protection function.

5. Protection functions

Each protection stage can independently be enabled or disabled according to the requirements of the intended application.

5.1. Maximum number of protection stages in one application

The device limits the maximum number of enabled stages to about 30, depending of the type of the stages. For more information, please see the configuration instructions in chapter 2.4.

5.2. List of protection functions

IEEE/ ANSI code	**IEC symbol**	**Function name**
50/51	3I>, 3I>>, 3I>>>	Overcurrent protection
67	I_{dir}>, I_{dir}>>, I_{dir}>>>, I_{dir}>>>>	Directional overcurrent protection
51V	Iv>	Voltage restrained or voltage controlled overcurrent function
46	I_2>	Current unbalance protection
49	T>	Thermal overload protection
50N/51N	I_0>, I_0>>, I_0>>>, I_0>>>>	Earth fault protection
67N	$I_{0\varphi}$>, $I_{0\varphi}$>>	Directional earth fault protection
67NT	I_{0T}	Intermittent transient earth fault protection
59	U>, U>>, U>>>	Overvoltage protection
27	U<, U<<, U<<<	Undervoltage protection
24	U/f>	Volts/hertz overexcitation protection
27P	U_1<, U_1<<	Positive sequence undervoltage protection
59N	U_0>, U_0>>	Residual voltage protection
64F3	U_{0f3}<	100 % stator earth fault protection
81H/81L	f><, f>><<	Overfrequency and underfrequency protection
81L	f<, f<<	Under frequency protection
81R	df/dt>	Rate of change of frequency (ROCOF) protection
21	Z<, Z<<	Underimpedance protection
40	Q<	Underexcitation protection
21/40	X<, X<<	Underreactance protection (Loss of excitation)
32	P<, P<<	Reverse and underpower protection
51F2	I_{f2}>	Second harmonic O/C stage
51F5	I_{f5}>	Fifth harmonic O/C stage
50BF	CBFP	Circuit-breaker failure protection
99	Prg1...8	Programmable stages

5.3. General features of protection stages

Setting groups

Most stages have two setting groups. Changing between setting groups can be controlled manually or using any of the digital inputs, virtual inputs, virtual outputs or LED indicator signals. By using virtual I/O the active setting group can be controlled using the local panel mimic display, any communication protocol or using the inbuilt programmable logic functions.

Forcing start or trip condition for testing

The status of a protection stage can be one of the followings:

- Ok = '–' The stage is not detecting any fault.
- Blocked The stage is detecting a fault but blocked by some reason.
- Start The stage is counting the operation delay.
- Trip The stage has tripped and the fault is still on.

The blocking reason may be an active signal via the block matrix from other stages, the programmable logic or any digital input. Some stages also have inbuilt blocking logic. For example an under frequency stage is blocked if voltage is too low. For more details about block matrix, see chapter 8.5.

Forcing start or trip condition for testing purposes

There is a "Force flag" parameter which, when activated, allows forcing the status of any protection stage to be "start" or "trip" for a half second. By using this forcing feature any current or voltage injection to the relay is not necessary to check the output matrix configuration, to check the wiring from the output relays to the circuit breaker and also to check that communication protocols are correctly transferring event information to a SCADA system.

After testing the force flag will automatically reset 5-minute after the last local panel push button activity.

The force flag also enables forcing of the output relays and forcing the optional mA outputs.

Start and trip signals

Every protection stage has two internal binary output signals: start and trip. The start signal is issued when a fault has been detected. The trip signal is issued after the configured operation delay unless the fault disappears before the end of the delay time.

Output matrix

Using the output matrix the user connects the internal start and trip signals to the output relays and indicators. For more details see chapter 8.4.

Blocking

Any protection function, except arc protection, can be blocked with internal and external signals using the block matrix (chapter 8.5). Internal signals are for example logic outputs and start and trip signals from other stages and external signals are for example digital and virtual inputs.

Some protection stages have also inbuilt blocking functions. For example under-frequency protection has inbuilt under-voltage blocking to avoid tripping when the voltage is off.

When a protection stage is blocked, it won't pick-up in case of a fault condition is detected. If blocking is activated during the operation delay, the delay counting is frozen until the blocking goes off or the pick-up reason, i.e. the fault condition, disappears. If the stage is already tripping, the blocking has no effect.

Retardation time

Retardation time is the time a protection relay needs to notice, that a fault has been cleared during the operation time delay. This parameter is important when grading the operation time delay settings between relays.

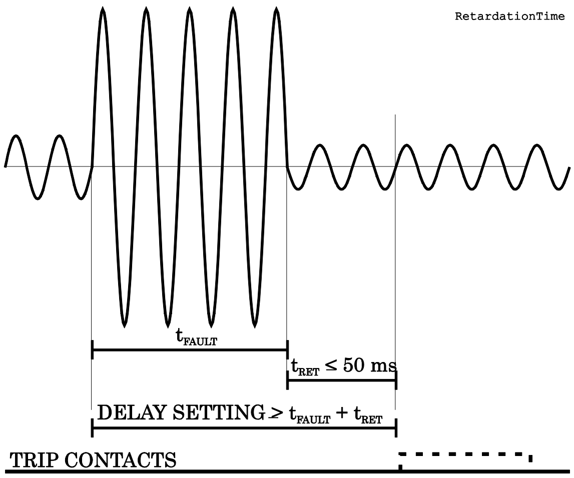


Figure 5.3-1 Definition for retardation time. If the delay setting would be slightly shorter, an unselective trip might occur (the dash line pulse).

For example when there is a big fault in an outgoing feeder, it might start i.e. pick-up both the incoming and outgoing feeder relay. However the fault must be cleared by the outgoing feeder relay and the incoming feeder relay must not trip. Although the operating delay setting of the incoming feeder is more than at the outgoing feeder, the incoming feeder might still trip, if the operation time difference is not big enough. The difference must be more than the retardation time of the incoming feeder relay plus the operating time of the outgoing feeder circuit breaker.

Figure 5.3-1 shows an overcurrent fault seen by the incoming feeder, when the outgoing feeder does clear the fault. If the operation delay setting would be slightly shorter or if the fault duration would be slightly longer than in the figure, an unselective trip might happen (the dashed 40 ms pulse in the figure). In VAMP relays the retardation time is less than 50 ms.

Reset time (release time)

Figure 5.3-2 shows an example of reset time i.e. release delay, when the relay is clearing an overcurrent fault. When the relay's trip contacts are closed the circuit breaker (CB) starts to open. After the CB contacts are open the fault current will still flow through an arc between the opened contacts. The current is finally cut off when the arc extinguishes at the next zero crossing of the current. This is the start moment of the reset delay. After the reset delay the trip contacts and start contact are opened unless latching is configured. The reset time varies from fault to fault depending on the fault size. After a big fault the time is longer. The reset time also depends on the specific protection stage. The maximum reset time for each stage is specified in chapter 12.3. For most stages it is less than 95 ms.

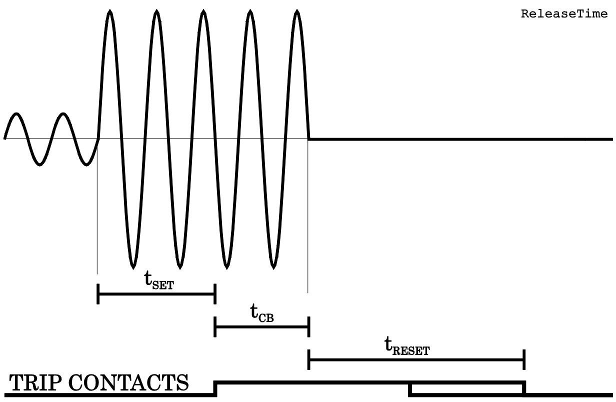


Figure 5.3-2 Reset time is the time it takes the trip or start relay contacts to open after the fault has been cleared.

Hysteresis or dead band

When comparing a measured value against a pick-up value, some amount of hysteresis is needed to avoid oscillation near equilibrium situation. With zero hysteresis any noise in the measured signal or any noise in the measurement itself would cause unwanted oscillation between fault-on and fault-off situations.

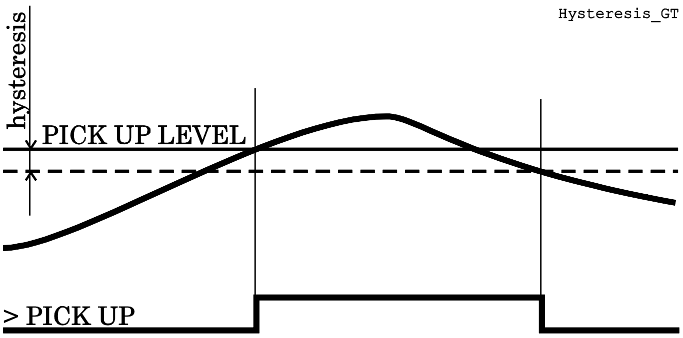


Figure 5.3-3 Behaviour of a greater than comparator. For example in overcurrent and overvoltage stages the hysteresis (dead band) acts according this figure.

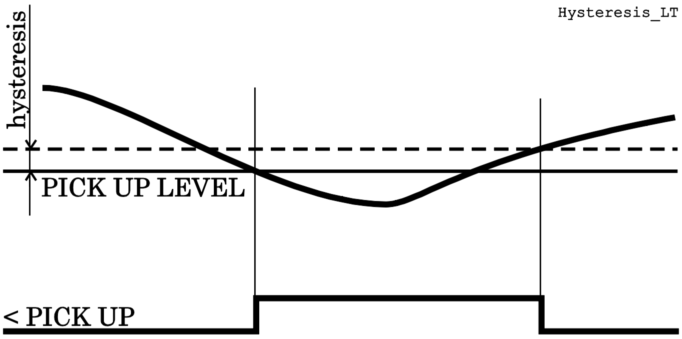


Figure 5.3-4 Behaviour of a less than comparator. For example in under-voltage and under frequency stages the hysteresis (dead band) acts according this figure.

5.4. Overcurrent protection I> (50/51)

Overcurrent protection is used against short circuit faults and heavy overloads.

The overcurrent function measures the fundamental frequency component of the phase currents. The protection is sensitive for the highest of the three phase currents. Whenever this value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation delay setting, a trip signal is issued.

Three independent stages

There are three separately adjustable overcurrent stages: I>, I>> and I>>>. The first stage I> can be configured for definite time (DT) or inverse time operation characteristic (IDMT). The stages I>> and I>>> have definite time operation characteristic. By using the definite delay type and setting the delay to its minimum, an instantaneous (ANSI 50) operation is obtained.

Figure 5.4-1 shows a functional block diagram of the I> overcurrent stage with definite time and inverse time operation time. Figure 5.4-2 shows a functional block diagram of the I>> and I>>> overcurrent stages with definite time operation delay.

Inverse operation time

Inverse delay means that the operation time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is the faster will be the operation. Accomplished inverse delays are available for the I> stage. The inverse delay types are described in chapter 5.29. The relay will show the currently used inverse delay curve graph on the local panel display.

Inverse time limitation

The maximum measured secondary current is $50xI_N$. This limits the scope of inverse curves with high pick-up settings. See chapter 5.29 for more information.

Cold load and inrush current handling

See chapter 6.3.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

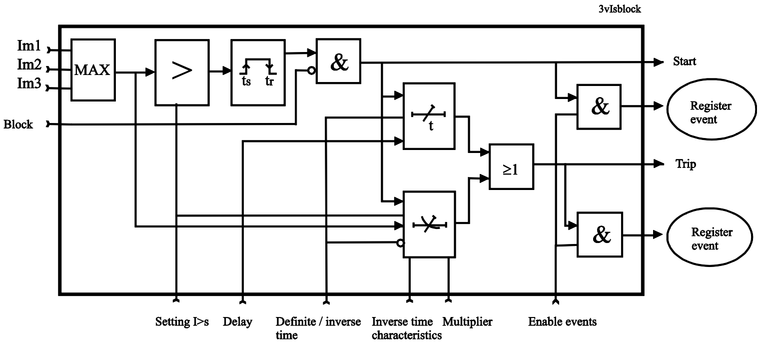


Figure 5.4-1 Block diagram of the three-phase overcurrent stage I>.

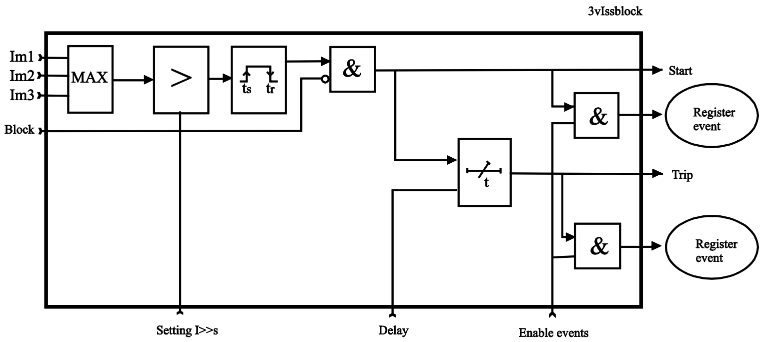


Figure 5.4-2 Block diagram of the three-phase overcurrent stage I>> and I>>>.

Parameters of the overcurrent stage I> (50/51)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set

Parameter	Value	Unit	Description	Note
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. This flag is automatically reset 5 minutes after the last front panel push button pressing.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
I>		A	Pick-up value scaled to primary value	
I>		xIgn	Pick-up setting	Set
Curve	 DT IEC IEEE IEEE2 RI PrgN		Delay curve family: Definite time Inverse time. See chapter 5.29. Pre 1996	Set
Type	 DT NI VI EI LTI Parameters		Delay type. Definite time Inverse time. See chapter 5.29.	Set
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Dly20x		s	Delay at 20xIset	
Dly4x		s	Delay at 4xIset	
Dly2x		s	Delay at 2xIset	
Dly1x		s	Delay at 1xIset	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See chapter 5.29.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Parameters of the overcurrent stages I>>, I>>> (50/51)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
I>>, I>>>		A	Pick-up value scaled to primary value	
I>>, I>>>		xIgn	Pick-up setting	Set
t>>, t>>>		s	Definite operation time	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault type, fault current, load current before the fault, elapsed delay and setting group.

Recorded values of the overcurrent stages (8 latest faults) I>, I>>, I>>> (50/51)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Type	 1-N 2-N 3-N 1-2 2-3 3-1 1-2-3		Fault type Ground fault Ground fault Ground fault Two phase fault Two phase fault Two phase fault Three phase fault
Flt		xIgn	Maximum fault current
Load		xIgn	1 s average phase currents before the fault
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.5. Directional overcurrent protection I_{dir}> (67)

Directional overcurrent protection can be used for directional short circuit protection. Typical applications are

- Short circuit protection of two parallel cables or overhead lines in a radial network.
- Short circuit protection of a looped network with single feeding point.
- Short circuit protection of a two-way feeder, which usually supplies loads but is used in special cases as an incoming feeder.
- Directional overcurrent protection in low impedance earthed networks. Please note that in this case the device has to connected to line-to-neutral voltages instead of line-to-line voltages. In other words the voltage measurement mode has to be "3LN" (See chapter 7.6).

The stages are sensitive to the amplitude of the highest fundamental frequency current of the three measured phase currents. The phase angle is based on the phase angle of the three-phase power phasor. For details of power direction see chapter 7.8. A typical characteristic is shown in Figure 5.5-1. The base angle setting is –30°. The stage will pick up, if the tip of the three phase current phasor gets into the grey area.

NOTE! If the maximum possible earth fault current is greater than the most sensitive directional over current setting, the device has to connected to the line-to-neutral voltages instead of line-to-line voltages in order to get the right direction for earth faults, too. (For networks having the maximum possible earth fault current less than the over current setting, use 67N, the directional earth fault stages.)

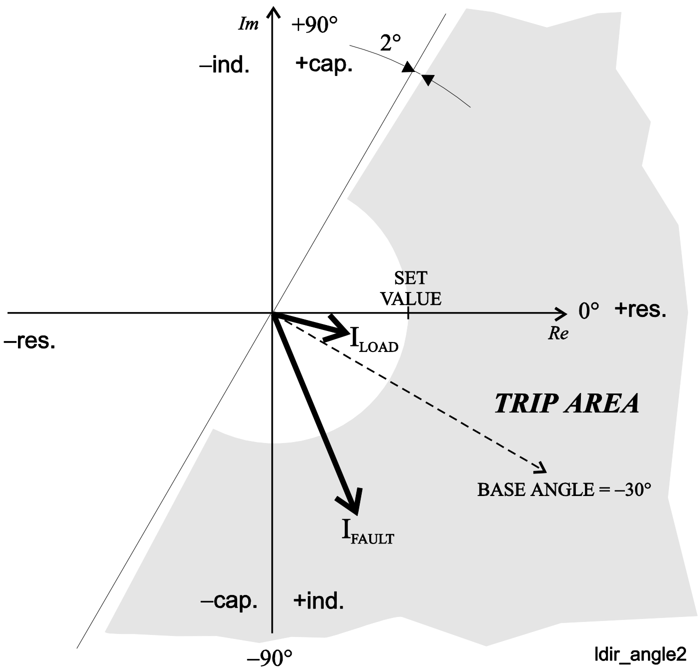


Figure 5.5-1 Example of protection area of the directional overcurrent function.

Two modes are available: directional and non-directional (Figure 5.5-2). In the non-directional mode the stage is acting just like an ordinary overcurrent 50/51 stage.

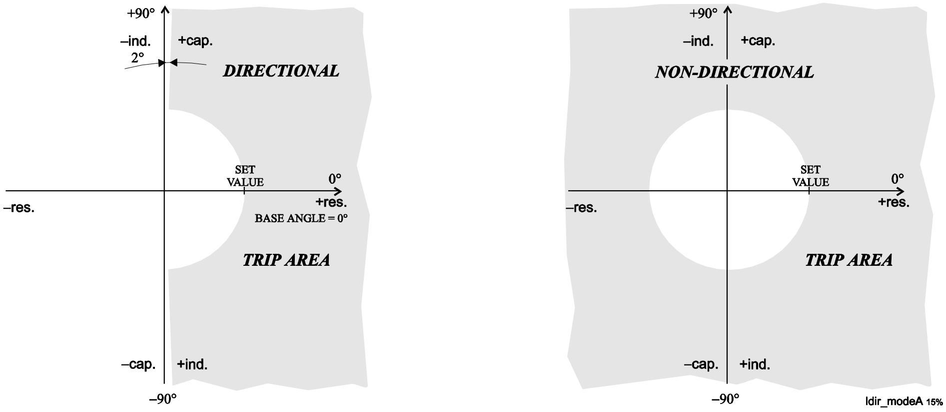


Figure 5.5-2 .Difference between directional mode and non-directional mode. The grey area is the trip region.

An example of bi-directional operation characteristic is shown in Figure 5.5-3. The right side stage in this example is the stage Idir> and the left side is Idir>>. The base angle setting of the Idir> is 0° and the base angle of Idir>> is set to –180°.

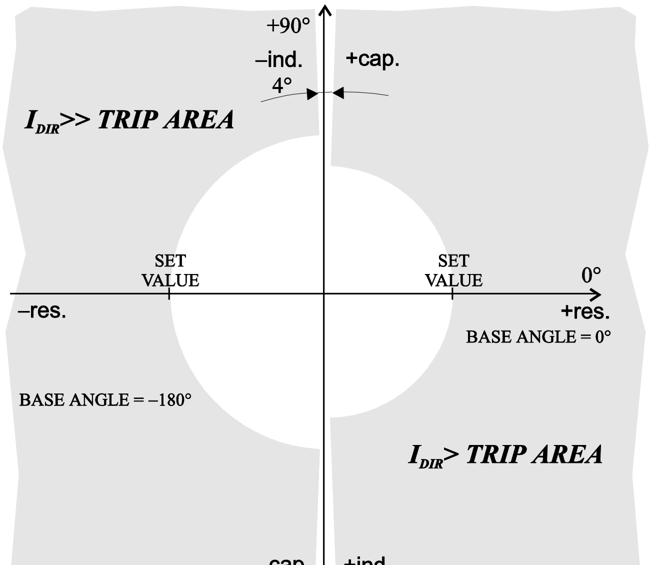


Figure 5.5-3 Bi-directional application with two stages Idir> and Idir>>.

When any of the three phase currents exceeds the setting value and – in directional mode – the phase angle including the base angle is within the active ±88° wide sector, the stage picks up and issues a start signal. If this fault situation remains on longer than the delay setting, a trip signal is issued.

Four independent stages

There are four separately adjustable stages available: I_{dir}>, I_{dir}>>, I_{dir}>>> and I_{dir}>>>>.

Inverse operation time

Stages I_{dir}> and I_{dir}>> can be configured for definite time or inverse time characteristic. See chapter 5.29 for details of the available inverse delays. Stages I_{dir}>>> and I_{dir}>>>> have definite time (DT) operation delay. The relay will show a scaleable graph of the configured delay on the local panel display.

Inverse time limitation

The maximum measured secondary current is $50xI_N$. This limits the scope of inverse curves with high pick-up settings. See chapter 5.29 for more information.

Cold load and inrush current handling

See chapter 6.3.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Figure 5.5-4 shows the functional block of the Idir> stage.

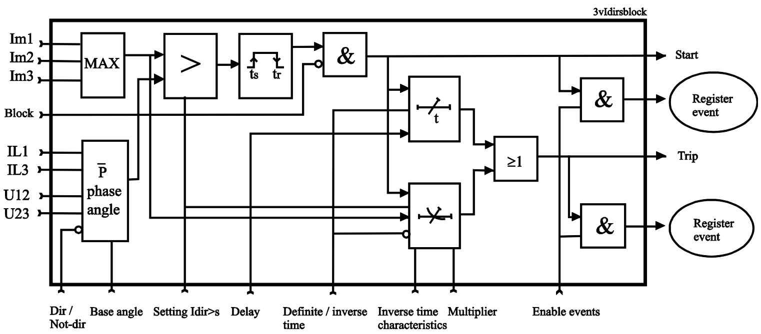


Figure 5.5-4 Block diagram of the three-phase overcurrent stage I_{dir}>

Parameters of the directional overcurrent stages I_{dir}>, I_{dir}>> (67)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	- DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set

Parameter	Value	Unit	Description	Note

Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
Iφ>, Iφ>>		A	Pick-up value scaled to primary value	
Iφ>, Iφ>>		xIgn	Pick-up setting	Set
Curve	 DT IEC IEEE IEEE2 RI PrgN		Delay curve family: Definite time Inverse time. See chapter 5.29.	Set
Type	 DT NI VI EI LTI Parameters		Delay type. Definite time Inverse time. See chapter 5.29.	Set
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Dly20x		s	Delay at 20xIset	
Dly4x		s	Delay at 4xIset	
Dly2x		s	Delay at 2xIset	
Dly1x		s	Delay at 1xIset	
Mode	Dir Undir		Directional mode (67) Undirectional (50/51)	Set
Offset		°	Angle offset in degrees	Set
φ		°	Measured power angle	
U1		%Un	Measured positive sequence voltage	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See chapter 5.29.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Parameters of the directional overcurrent stages I_{dir}>>>, I_{dir}>>>> (67)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
Iφ>>>> Iφ>>>>>		A	Pick-up value scaled to primary value	
Iφ>>>> Iφ>>>>>		xIgn	Pick-up setting	Set
t>>> t>>>>		s	Definite operation time (for definite time only)	Set
Mode	Dir Undir		Directional (67) Undirectional (50/51)	Set
Offset		°	Angle offset in degrees	Set
φ		°	Measured power angle	
U1		%Un	Measured positive sequence voltage	

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault type, fault current, load current before the fault, elapsed delay and setting group.

Recorded values of the directional overcurrent stages (8 latest faults) I_{dir}>, I_{dir}>>, I_{dir}>>>, I_{dir}>>>> (67)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Type			Fault type
	1-N		Ground fault
	2-N		Ground fault
	3-N		Ground fault
	1-2		Two phase fault
	2-3		Two phase fault
	3-1		Two phase fault
	1-2-3		Three phase fault
Flt		xIgn	Maximum fault current
Load		xIgn	1 s average phase currents before the fault
EDly		%	Elapsed time of the operating time setting. 100% = trip
Angle		°	Fault angle in degrees
U1		xUn	Positive sequence voltage during fault
SetGrp	1 2		Active setting group during fault

5.6. Voltage restrained/controlled overcurrent function I_V> (51V)

The voltage restrained overcurrent stage I_V> is used for generator short-circuit protection in applications, where the static excitation system of the generator is fed only from the generator terminals.

In these applications the operation of the high set overcurrent function must be secured using a voltage restrained overcurrent function. At close-by short circuits the fault current rapidly decreases, thus jeopardizing the operation of the high set short-circuit protection. The operation characteristic of a voltage restrained overcurrent function is shown in Figure 5.6-1. The under impedance protection (see chapter 5.20) can be used for the same purpose.

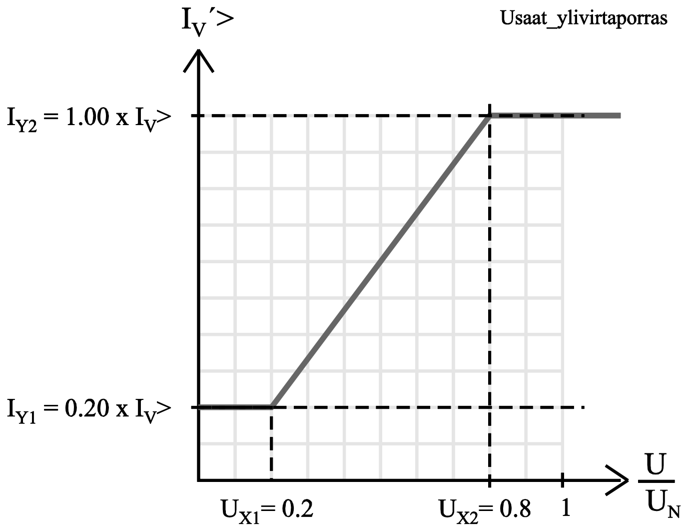


Figure 5.6-1 Characteristics of a voltage restrained overcurrent function I_V>.

When the generator pole voltage falls below the set voltage level, the start current level of the overcurrent stage I_V> also starts falling linearly controlled by the voltage according to the characteristic curve in Figure 5.6-1.

When the setting parameters are selected according to Figure 5.6-2, the function is said to be voltage controlled.

NOTE! The overcurrent function can be used as a normal high-set overcurrent stage I>>>, if IY1 and IY2 are set to 100%.

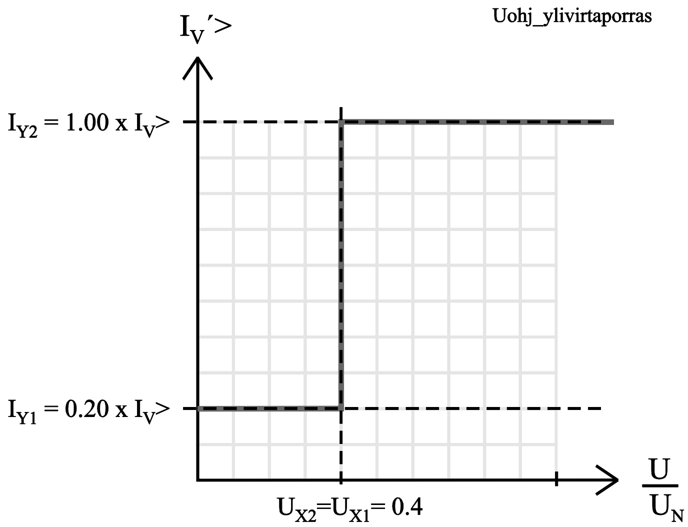


Figure 5.6-2 Voltage controlled overcurrent characteristics.

The voltage setting parameters U_{X1} and U_{X2} are proportional to the rated voltage of the generator. They define the voltage limits, within which the start current of the overcurrent unit is restrained. The multipliers I_{Y1} and I_{Y2} are used for setting the area of change of the start level of the overcurrent function in proportion to the U_{X1} and U_{X2} settings.

The voltage restrained/controlled overcurrent stage operates with definite time characteristic. The start current I_V> and the operating time t> can be set by the user.

Cold load and inrush current handling

See chapter 6.3.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the voltage restrained and voltage-controlled overcurrent stage I_V> (51V)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
Iv>		A	Pick-up value scaled to primary value	
Iv>		xIgn	Pick-up setting	Set
t>		s	Definite operation time	Set
X1		%U1	Voltage for the 1st knee point.	Set
X2		%U1	Voltage for the 2nd knee point	Set
Y1		%Iv>	Multiplier for pick-up setting at the 1st knee point	Set
Y2		%Iv>	Multiplier for pick-up setting at the 2nd knee point	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault type, fault current, load current before the fault, elapsed delay and setting group.

Recorded values of the voltage restrained/controlled overcurrent stages (8 latest faults) I_V> (51V)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Type			Fault type
	1-N		Ground fault
	2-N		Ground fault
	3-N		Ground fault
	1-2		Two phase fault
	2-3		Two phase fault
	3-1		Two phase fault
	1-2-3		Three phase fault
Flt		xIgn	Maximum fault current
Load		xIgn	1 s average phase currents before the fault
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp			Active setting group during the fault

5.7. Current unbalance protection I_2> (46)

Current unbalance in a generator causes double frequency currents in the rotor. This warms up the surface of the rotor and the available thermal capacity of the rotor is much less than the thermal capacity of the whole generator. Thus an rms current based overload protection (see chapter 5.8) is not capable to protect a generator against current unbalance.

The current unbalance protection is based on the negative sequence of the base frequency phase currents. Both definite time and inverse time characteristics are available.

Inverse delay

The inverse delay is based on the following equation.

Equation 5.7-1

$$t = \frac{K_1}{\left(\frac{I_2}{I_{gn}}\right)^2 - K_2^2}$$, where

t	=	Operation time
K_1	=	Delay multiplier
I_2	=	Measured and calculated negative sequence phase current of fundamental frequency.
I_{gn}	=	Rated current of the generator
K_2	=	Pick-up setting I_2> in pu. The maximum allowed degree of unbalance.

Example:

K_1	=	15 s
I_2	=	22.9 % = 0.229 xI_{gn}
K_2	=	5 % = 0.05 xI_{gn}

$$t = \frac{15}{\left(\frac{0.229}{1}\right)^2 - 0.05^2} = 300.4$$

The operation time in this example will be five minutes.

More stages (definite time delay only)

If more than one definite time delay stages are needed for current unbalance protection, the freely programmable stages can be used (chapter 5.27).

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

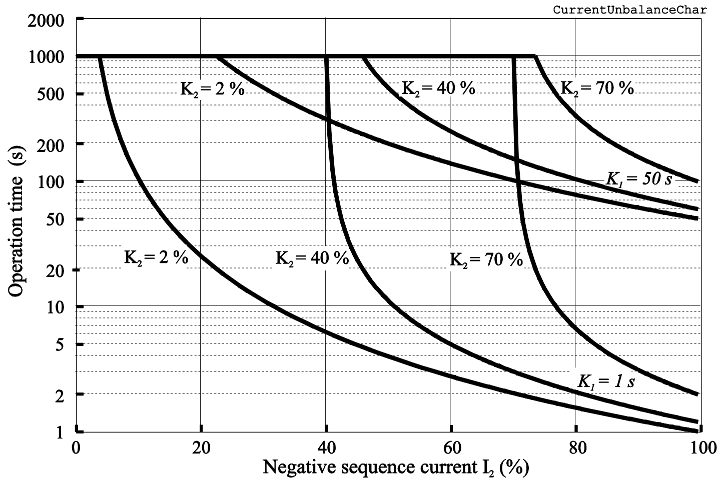


Figure 5.7-1 Inverse operation delay of current unbalance stage I_2>. The longest delay is limited to 1000 seconds (=16min 40s).

Parameters of the current unbalance stage I_2> (46)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
I2/Ign		%Ign	The supervised value.	
I2>		%Ign	Pick-up setting	Set
t>		s	Definite operation time (Type=DT)	Set
Type	DT INV		Definite time Inverse time (Equation 5.7-1)	Set
K1		s	Delay multiplier (Type =INV)	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There is detailed information available of the eight latest faults: Time stamp, unbalance current, elapsed delay and setting group.

Recorded values of the current unbalance stage (8 latest faults) I_2> (46)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%Ign	Maximum unbalance current
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during the fault

5.8. Thermal overload protection T> (49)

The thermal overload function protects the generator stator windings against excessive temperatures.

Thermal model

The temperature is calculated using rms values of phase currents and a thermal model according IEC 60255-8. The rms values is calculated using harmonic components up to the 15^{th}.

Trip time: $t = \tau \cdot \ln \dfrac{I^2 - I_P{}^2}{I^2 - a^2}$

Alarm: $a = k \cdot k_\Theta \cdot I_{GN} \cdot \sqrt{alarm}$ (Alarm 60% = 0.6)

Trip: $a = k \cdot k_\Theta \cdot I_{GN}$

Release time: $t = \tau \cdot C_\tau \cdot \ln \dfrac{I_P{}^2}{a^2 - I^2}$

Trip release: $a = \sqrt{0.95} \times k_\Theta \times I_{GN}$

Start release: $a = \sqrt{0.95} \times k_\Theta \times I_{GN} \times \sqrt{alarm}$ (Alarm 60% = 0.6)

T	=	Operation time
τ	=	Thermal time constant tau (Setting value)
ln	=	Natural logarithm function
I	=	Measured rms phase current (the max. value of three phase currents)
Ip	=	Preload current, $I_P = \sqrt{\theta} \times k_\Theta \times I_{GN}$ (If temperature rise is 120%→ $\theta = 1.2$). This parameter is the memory of the algorithm and corresponds to the actual temperature rise.
k	=	Overload factor (Maximum continuous current, i.e. service factor. (Setting value)
kΘ	=	Ambient temperature factor (Permitted current due to tamb) Figure 5.8-1
I_{GN}	=	The rated current (I_N or I_{MOT})
C_τ	=	Cooling time coefficient (cooling time constant = C_τ x τ)

Time constant for cooling situation

If the generator's fan is stopped, the cooling will be slower than with an active fan. Therefore there is a coefficient cτ for thermal constant available to be used as cooling time constant, when current is less than 0.3xI_{GN}.

Heat capacitance, service factor and ambient temperature

The trip level is determined by the maximum allowed continuous current I_{MAX} corresponding to the 100 % temperature rise Θ_{TRIP} i.e. the heat capacitance of the generator. I_{MAX} depends of the given service factor k and ambient temperature Θ_{AMB} and settings I_{MAX40} and I_{MAX70} according the following equation.

$$I_{MAX} = k \cdot k_{\Theta} \cdot I_{GN}$$

The value of ambient temperature compensation factor kΘ depends on the ambient temperature Θ_{AMB} and settings I_{MAX40} and I_{MAX70}. See **Error! Reference source not found.**. Ambient temperature is not in use when kΘ = 1. This is true when

- I_{MAX40} is 1.0
- Samb is “n/a” (no ambient temperature sensor)
- TAMB is +40 °C.

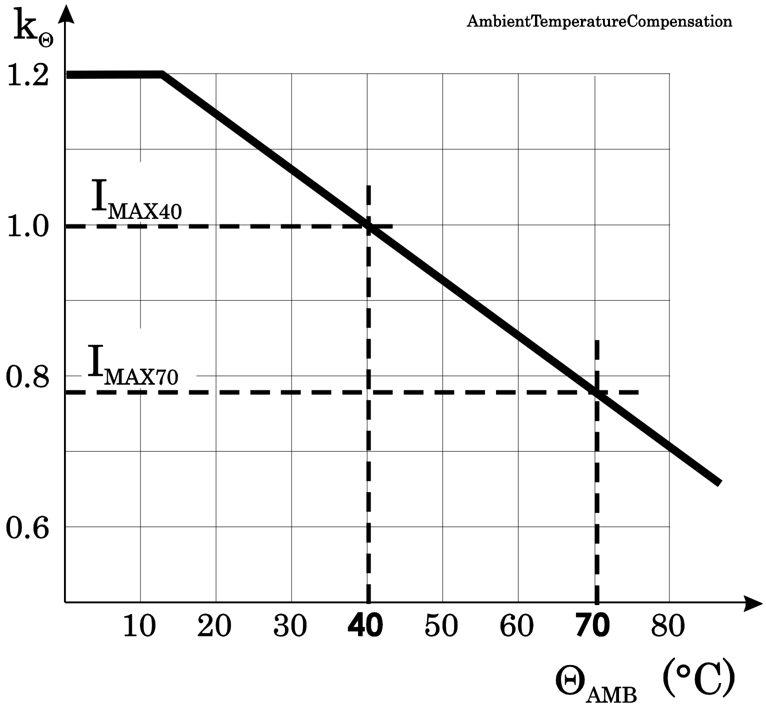


Figure 5.8-1 Ambient temperature correction of the overload stage T>.

Example of a behaviour of the thermal model

Figure 5.8-2 shows an example of the thermal model behaviour. In this example τ = 30 minutes, k = 1.06 and kΘ = 1 and the current has been zero for a long time and thus the initial temperature rise is 0 %. At time = 50 minutes the current changes to $0.85xI_{GN}$ and the temperature rise starts to approach value $(0.85/1.06)^2$ = 64 % according the time constant. At time=300 min, the temperature is about stable, and the current increases to 5 % over the maximum defined by the rated current and the service factor k. The temperature rise starts to approach value 110 %. At about 340 minutes the temperature rise is 100 % and a trip follows.

Initial temperature rise after restart

When the relay is switched on, an initial temperature rise of 70 % is used. Depending of the actual current, the calculated temperature rise then starts to approach the final value.

Alarm function

The thermal overload stage is provided with a separately settable alarm function. When the alarm limit is reached the stage activates its start signal.

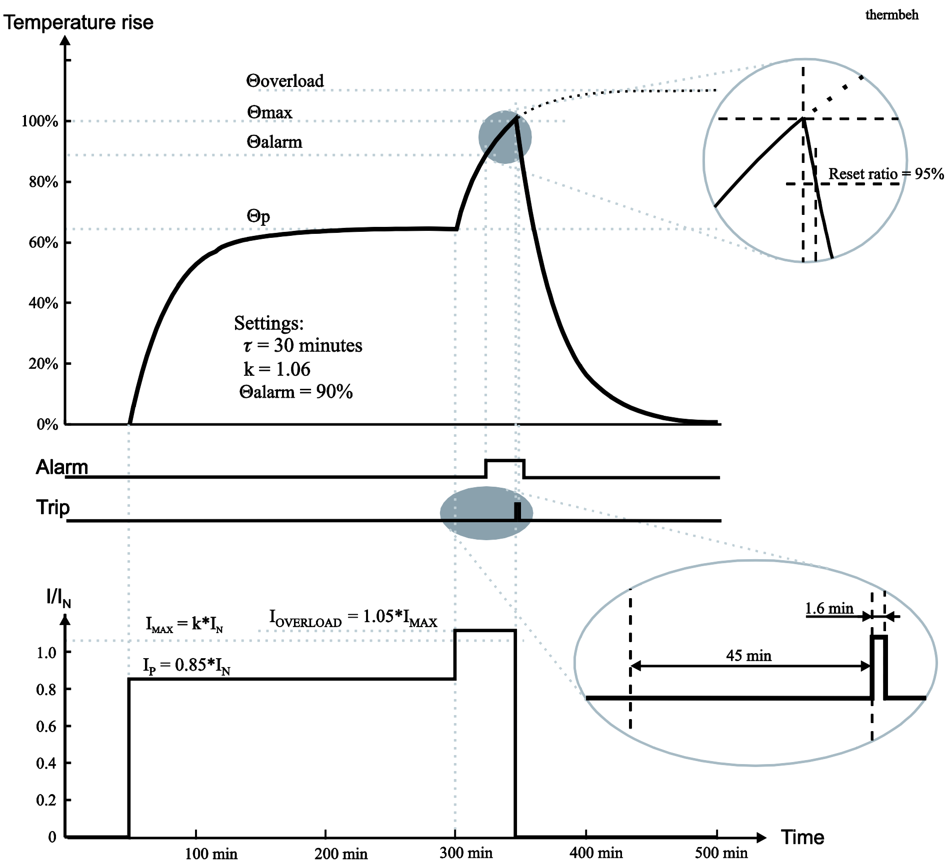


Figure 5.8-2 Example of the thermal model behaviour.

Parameters of the thermal overload stage T> (49)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
Time	hh:mm:ss		Estimated time to trip	
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
T		%	Calculated temperature rise. Trip limit is 100 %.	F
MaxRMS		Arms	Measured current. Highest of the three phases.	
Imax		A	kxIgn. Current corresponding to the 100 % temperature rise.	
k>		xIgn	Allowed overload (service factor)	Set
Alarm		%	Alarm level	Set
tau		min	Thermal time constant	Set
ctau		xtau	Coefficient for cooling time constant. Default = 1.0	Set
kTamb		xIgn	Ambient temperature corrected max. allowed continuous current	
Imax40		%Ign	Allowed load at Tamb +40 °C. Default = 100 %.	Set
Imax70		%Ign	Allowed load at Tamb +70 °C.	Set
Tamb		°C	Ambient temperature. Editable Samb=n/a. Default = +40 °C	Set
Samb	 n/a ExtAI1...16		Sensor for ambient temperature No sensor in use for Tamb External Analogue input 1...16	 Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

5.9. Earth fault protection I_0> (50N/51N)

Undirectional earth fault protection is used for generator's stator earth faults in low impedance earthed networks. In high impedance earthed networks, compensated networks and isolated networks undirectional earth fault can be used as back-up protection.

The undirectional earth fault function is sensitive to the fundamental frequency component of the residual current $3I_0$. The attenuation of the third harmonic is more than 60 dB. Whenever this fundamental value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

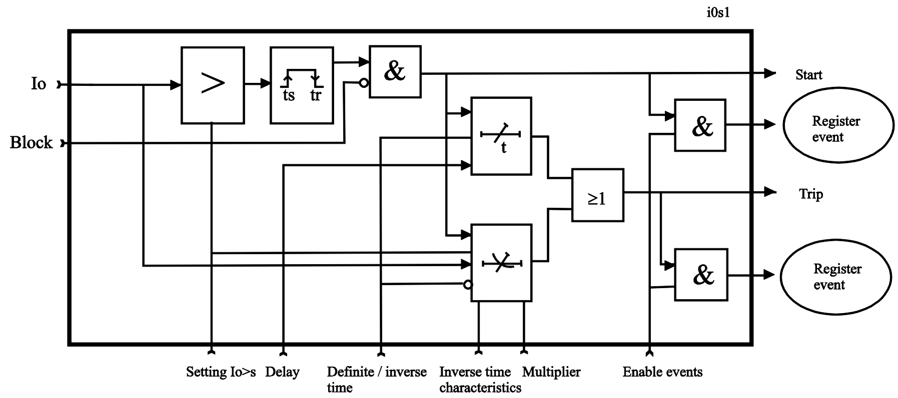


Figure 5.9-1 Block diagram of the earth fault stage I_0>

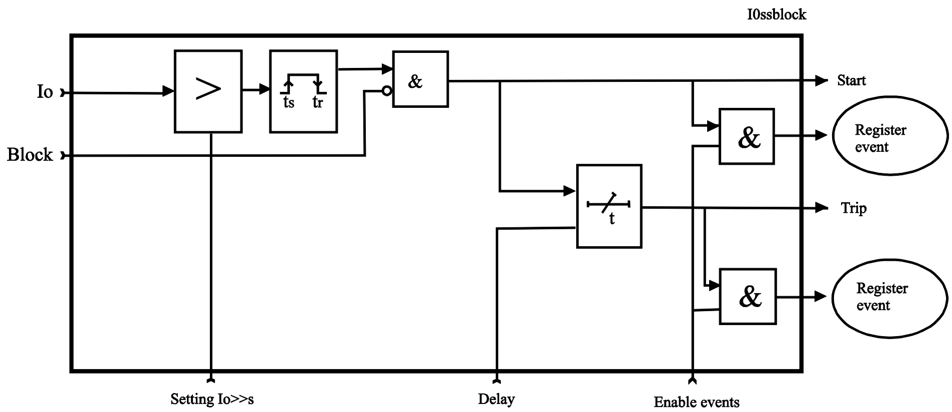


Figure 5.9-2 Block diagram of the earth fault stages I_0>>, I_0>>> and I_0>>>>

Figure 5.9-1 shows a functional block diagram of the I_0> earth overcurrent stage with definite time and inverse time operation time. Figure 5.9-2 shows a functional block diagram of the I_0>>, I_0>>> and I_0>>>> earth fault stages with definite time operation delay.

Input signal selection

Each stage can be connected to supervise any of the following inputs and signals:

- Input I_{01} for all networks other than rigidly earthed.
- Input I_{02} for all networks other than rigidly earthed.
- Calculated signal I_{0Calc} for rigidly and low impedance earthed networks. $I_{0Calc} = I_{L1} + I_{L2} + I_{L3}$.

Additionally the stage I_0> have two more input signal alternatives to measure current peaks to detect a restriking intermittent earth fault:

- I_{01Peak} to measure the peak value of input I_{01}.
- I_{02Peak} to measure the peak value of input I_{02}.

Intermittent earth fault detection

Short earth faults make the protection to start (to pick up), but will not cause a trip. (Here a short fault means one cycle or more. For shorter than 1 ms transient type of intermittent earth faults in compensated networks there is a dedicated stage Iot> 67NT.)

When starting happens often enough, such intermittent faults can be cleared using the intermittent time setting. When a new start happens within the set intermittent time, the operation delay counter is not cleared between adjacent faults and finally the stage will trip.

Four or six independent undirectional earth fault overcurrent stages

There are four separately adjustable earth fault stages: I_0>, I_0>>, I_0>>>, and I_0>>>>. The first stage I_0> can be configured for definite time (DT) or inverse time operation characteristic (IDMT). The other stages have definite time operation characteristic. By using the definite delay type and setting the delay to its minimum, an instantaneous (ANSI 50N) operation is obtained.

Using the directional earth fault stages (chapter 5.10) in undirectional mode, two more stages with inverse operation time delay are available for undirectional earth fault protection.

Inverse operation time (I_0> stage only)

Inverse delay means that the operation time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is the faster will be the operation. Accomplished inverse delays are available for the I_0> stage. The inverse delay types are described in chapter 5.29. The relay will show a scaleable graph of the configured delay on the local panel display.

Inverse time limitation

The maximum measured secondary residual current is $10xI_{0N}$ and maximum measured phase current is $50xI_N$. This limits the scope of inverse curves with high pick-up settings. See chapter 5.29 for more information.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the undirectional earth fault stage I_0> (50N/51N)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Io Io2 IoCalc IoPeak Io2Peak		pu	The supervised value according the parameter "Input" below.	
Io>		A	Pick-up value scaled to primary value	
Io>		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set

Parameter	Value	Unit	Description	Note
Curve	 DT IEC IEEE IEEE2 RI PrgN		Delay curve family: Definite time Inverse time. See chapter 5.29.	Set
Type	 DT NI VI EI LTI Parameters		Delay type. Definite time Inverse time. See chapter 5.29.	Set
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Input	Io1 Io2 IoCalc Io1Peak Io2Peak		X1-7&8. See chapter 11 X1-9&10 IL1 + IL2 + IL3 X1-7&8 peak mode X1-9&10 peak mode	Set
Intrmt		s	Intermittent time	Set
Dly20x		s	Delay at 20xIset	
Dly4x		s	Delay at 4xIset	
Dly2x		s	Delay at 2xIset	
Dly1x		s	Delay at 1xIset	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See chapter 5.29.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Parameters of the undirectional earth fault stages I_0>>, I_0>>>, I_0>>>> (50N/51N)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Io Io2 IoCalc		pu	The supervised value according the parameter "Input" below.	
Io>> Io>>> Io>>>>		A	Pick-up value scaled to primary value	
Io>> Io>>> Io>>>>		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set
t>		s	Definite operation time (for definite time only)	Set
Input	Io1 Io2 IoCalc		X1-7&8. See chapter 11 X1-9&10 IL1 + IL2 + IL3	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There is detailed information available of the eight latest earth faults: Time stamp, fault current, elapsed delay and setting group.

Recorded values of the undirectional earth fault stages (8 latest faults) I_0>, I_0>>, I_0>>>, I_0>>>> (50N/51N)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		pu	Maximum earth fault current
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.10. Directional earth fault protection $I_{0\varphi}$> (67N)

The directional earth fault protection is used for generator's stator earth faults in networks where a selective and sensitive earth fault protection is needed and in applications with varying network structure and length.

The relay consists of versatile protection functions for earth fault protection in various network types.

The function is sensitive to the fundamental frequency component of the residual current and zero sequence voltage and the phase angle between them. The attenuation of the third harmonic is more than 60 dB. Whenever the size of I_0 and U_0 and the phase angle between I_0 and $-U_0$ fulfils the pick-up criteria, the stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Polarization

The negative zero sequence voltage $-U_0$ is used for polarization i.e. the angle reference for I_0. This $-U_0$ voltage is measured via energizing input U_0 or it is calculated from the phase voltages internally depending on the selected voltage measurement mode (see chapter 7.6):

- LN: the zero sequence voltage is calculated from the phase voltages and therefore any separate zero sequence voltage transformers are not needed. The setting values are relative to the configured voltage transformer (VT) voltage/√3.
- LL+U_0: The zero sequence voltage is measured with voltage transformer(s) for example using a broken delta connection. The setting values are relative to the VT_0 secondary voltage defined in configuration.

NOTE! The U_0 signal must be connected according the connection diagram (Figure 10.2-1) in order to get a correct polarization. Please note that actually the negative U_0, $-U_0$, is connected to the relay.

Modes for different network types

The available modes are:

- ResCap
  This mode consists of two sub modes, Res and Cap. A digital signal can be used to dynamically switch between these two sub modes. This feature can be used with compensated networks, when the Petersen coil is temporarily switched off.
    - Res
      The stage is sensitive to the resistive component of the selected I_0 signal. This mode is used with compensated **networks** (resonant grounding) and **networks earthed with a high resistance.** Compensation is usually done with a Petersen coil between the neutral point of the main transformer and earth. In this context "high resistance" means, that the fault current is limited to be less than the rated phase current. The trip area is a half plane as drawn in Figure 5.10-2. The base angle is usually set to zero degrees.
    - Cap
      The stage is sensitive to the capacitive component of the selected I0 signal. This mode is used with **unearthed networks.** The trip area is a half plane as drawn in Figure 5.10-2. The base angle is usually set to zero degrees.
- Sector
  This mode is used with **networks earthed with a small resistance.** In this context "small" means, that a fault current may be more than the rated phase currents. The trip area has a shape of a sector as drawn in Figure 5.10-3. The base angle is usually set to zero degrees or slightly on the lagging inductive side (i.e. negative angle).
- Undir
  This mode makes the stage equal to the undirectional stage I_0>. The phase angle and U_0 amplitude setting are discarded. Only the amplitude of the selected I_0 input is supervised.

Input signal selection

Each stage can be connected to supervise any of the following inputs and signals:

- Input I_{01} for all networks other than rigidly earthed.
- Input I_{02} for all networks other than rigidly earthed.
- Calculated signal I_{0Calc} for rigidly and low impedance earthed networks. $I_{0Calc} = I_{L1} + I_{L2} + I_{L3} = 3I_0$.

Additionally the stage $I_0\varphi$> have two more input signal alternatives to measure current peaks to detect short restriking intermittent earth faults:

- I_{01Peak} to measure the peak value of input I_{01}.
- I_{02Peak} to measure the peak value of input I_{02}.

Intermittent earth fault detection

Short earth faults make the protection to start (to pick up), but will not cause a trip. (Here a short fault means one cycle or more. For shorter than 1 ms transient type of intermittent earth faults in compensated networks there is a dedicated stage Iot> 67NT.)

When starting happens often enough, such intermittent faults can be cleared using the intermittent time setting. When a new start happens within the set intermittent time, the operation delay counter is not cleared between adjacent faults and finally the stage will trip.

Two independent stages

There are two separately adjustable stages: Iφ> and Iφ>>. Both the stages can be configured for definite time delay (DT) or inverse time delay operation time.

Inverse operation time

Inverse delay means that the operation time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is the faster will be the operation. Accomplished inverse delays are available for both stages $I_0\varphi>$ and $I_0\varphi>>$. The inverse delay types are described in chapter 5.29. The relay will show a scaleable graph of the configured delay on the local panel display.

Inverse time limitation

The maximum measured secondary residual current is $10xI_{0N}$ and maximum measured phase current is $50xI_N$. This limits the scope of inverse curves with high pick-up settings. See chapter 5.29 for more information.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

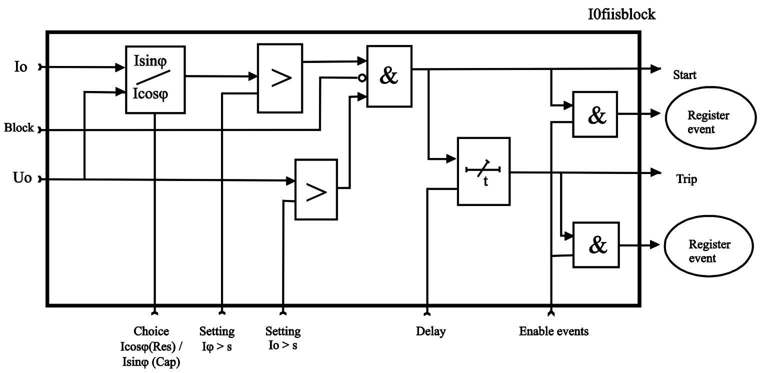


Figure 5.10-1 Block diagram of the directional earth fault stages $I_0\varphi>$ and $I_0\varphi>>$

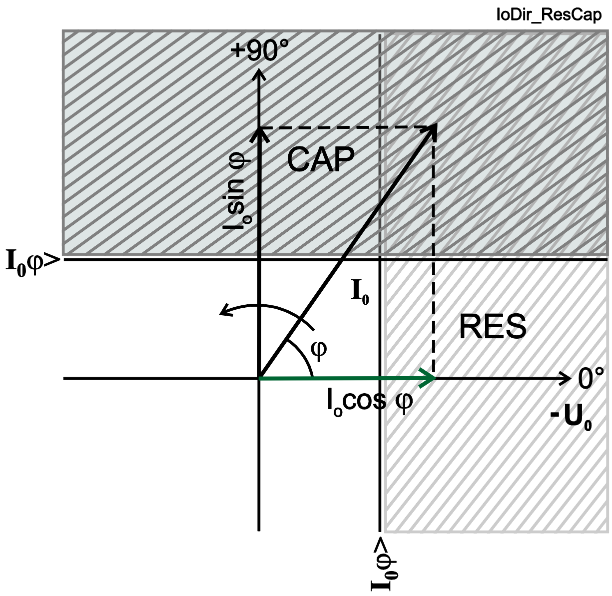


Figure 5.10-2 Operation characteristic of the directional earth fault protection in Res or Cap mode. Res mode can be used with compensated networks and Cap mode is used with ungrounded networks.

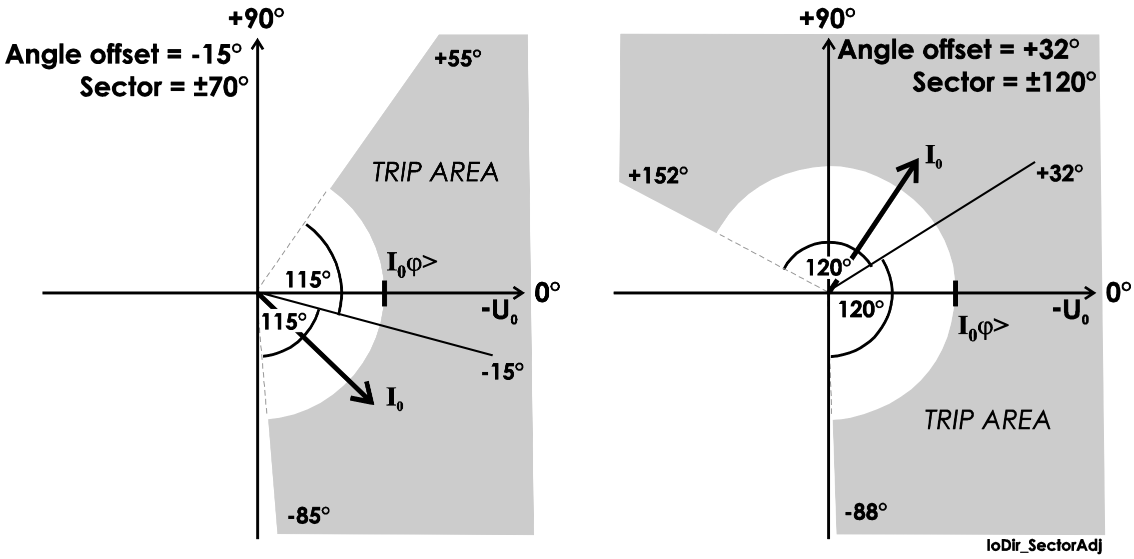


Figure 5.10-3 Two examples of operation characteristics of the directional earth fault stages in sector mode. The drawn I_0 phasor in both figures is inside the trip area. The angle offset and half sector size are user's parameters.

Parameters of the directional earth fault stages $I_0\varphi$>, $I_0\varphi$>> (67N)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Io Io2 IoCalc IoPeak Io2Peak		pu	The supervised value according the parameter "Input" below. ($I_0\varphi$> only) ($I_0\varphi$> only)	
IoRes		pu	Resistive part of I_0 (only when "InUse"=Res)	
IoCap		pu	Capacitive part of I_0 (only when "InUse"=Cap)	
Ioφ>		A	Pick-up value scaled to primary value	
Ioφ>		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set
Uo>		%	Pick-up setting for U_0	Set
Uo		%	Measured U_0	
Curve	 DT IEC IEEE IEEE2 RI PrgN		Delay curve family: Definite time Inverse time. See chapter 5.29.	Set
Type	 DT NI VI EI LTI Parameters		Delay type. Definite time Inverse time. See chapter 5.29.	Set

Parameter	Value	Unit	Description	Note
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Mode	ResCap Sector Undir		High impedance earthed nets Low impedance earthed nets Undirectional mode	Set
Offset		°	Angle offset for RecCap and Sector modes	Set
ChCtrl	 Res Cap DI1...6 VI1..4		Res/Cap control in mode ResCap Fixed to Resistive characteristic Fixed to Capacitive characteristic Controlled by digital input Controlled by virtual input	Set
InUse	 - Res Cap		Selected submode in mode ResCap. Mode is not ResCap Submode = resistive Submode = capacitive	
Input	Io1 Io2 IoCalc Io1Peak Io2Peak		X1-7&8. See chapter 11 X1-9&10 IL1 + IL2 + IL3 X1-7&8 peak mode ($I_0\varphi$> only) X1-9&10 peak mode ($I_0\varphi$> only)	Set
Intrmt		s	Intermittent time	Set
Dly20x		s	Delay at 20xIset	
Dly4x		s	Delay at 4xIset	
Dly2x		s	Delay at 2xIset	
Dly1x		s	Delay at 1xIset	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See chapter 5.29.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There is detailed information available of the eight latest earth faults: Time stamp, fault current, elapsed delay and setting group.

Recorded values of the directional earth fault stages (8 latest faults) $I_0\varphi$>, $I_0\varphi$>> (67N)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		pu	Maximum earth fault current
EDly		%	Elapsed time of the operating time setting. 100% = trip
Angle	°		Fault angle of I_0. $-U_0 = 0°$
Uo		%	Max. U_0 voltage during the fault
SetGrp	1 2		Active setting group during fault

5.11. Intermittent transient earth fault protection I_{0INT}> (67NI)

NOTE! This function is available only in voltage measurement modes[1], which include direct -U_0 measurement like for example $2U_{LL}+U_0$, but not for example in mode $3U_{LN}$.

The directional intermittent transient earth fault protection is used to detect short intermittent transient faults in compensated cable networks. The transient faults are self extinguished at some zero crossing of the transient part of the fault current I_{Fault} and the fault duration is typically only 0.1 ms ... 1 ms. Such short intermittent faults can not be correctly recognized by normal directional earth fault function using only the fundamental frequency components of I_0 and U_0.

Although a single transient fault usually self extinguishes within less than one millisecond, in most cases a new fault happens when the phase-to-earth voltage of the faulty phase has recovered (Figure 5.11-1).

[1] The voltage measurement modes are described in a separate chapter.

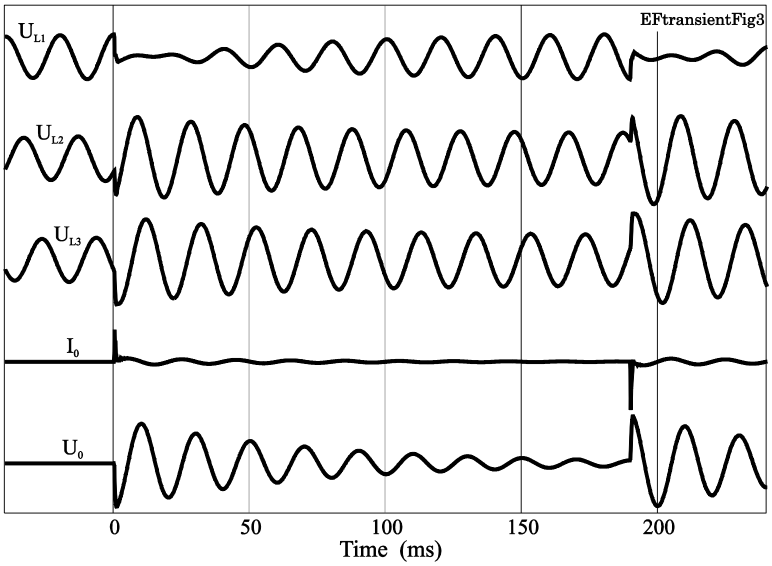


Figure 5.11-1 Typical phase to earth voltages, residual current of the faulty feeder and the zero sequence voltage U_0 during two transient earth faults in phase L1. In this case the network is compensated.

Direction algorithm

The function is sensitive to the instantaneous sampled values of the residual current and zero sequence voltage. The selected voltage measurement mode has to include a direct $-U_0$ measurement.

I_0 pick-up sensitivity

The sampling time interval of the relay is 625 μs at 50 Hz (32 samples/cycle). The I_0 current spikes can be quite short compared to this sampling interval. Fortunately the current spikes in cable networks are high and while the anti-alias filter of the relay is attenuates the amplitude, the filter also makes the pulses wider. Thus, when the current pulses are high enough, it is possible to detect pulses, which have duration of less than twenty per cent of the sampling interval. Although the measured amplitude can be only a fraction of the actual peak amplitude it doesn't disturb the direction detection, because the algorithm is more sensitive to the sign and timing of the I_0 transient than sensitive to the absolute amplitude of the transient. Thus a fixed value is used as a pick up level for the I_0.

Co-ordination with U_0> back up protection

Especially in a fully compensated situation, the zero sequence voltage back up protection stage U_0> for the bus may not release between consecutive faults and the U_0> might finally do an unselective trip if the intermittent transient stage I_{0INT}> doesn't operate fast enough. The actual operation time of the I_{0INT}> stage is very dependent on the behaviour of the fault and the intermittent time setting. To make the co-ordination between U_0> and I_{0INT}> more simple, the start signal of the transient stage I_{0INT}> in an outgoing feeder can be used to block the U_0> backup protection.

Co-ordination with the normal directional earth fault protection based on fundamental frequency signals

The intermittent transient earth fault protection stage I_{0INT}> should always be used together with the normal directional earth fault protection stages Iφ>, Iφ>>. The transient stage I_{0INT}> may in worst case detect the start of a steady earth fault in wrong direction, but will not trip because the peak value of a steady state sine wave I_0 signal must also exceed the corresponding base frequency component's peak value in order to make the I_{0INT}> to trip.

The operation time and U_0 setting of the transient stage I_{0INT}> should be higher than the settings of any Iφ> stage to avoid any unnecessary and possible incorrect start signals from the I_{0INT}> stage.

Auto reclosing

The start signal of any Iφ> stage initiating auto reclosing (AR) can be used to block the I_{0INT}> stage to avoid the I_{0INT}> stage with a long intermittent setting to interfere with the AR cycle in the middle of discrimination time.

Usually the I_{0INT}> stage itself is not used to initiate any AR. For transient faults the AR will not help, because the fault phenomena itself already includes repeating self extinguishing.

Intermittent time

Single transient faults make the protection to pick up, but will not cause trip if the stage has time to release between to successive faults. When starting happens often enough, such intermittent faults can be cleared using the intermittent time setting.

When a new fault happens within the set intermittent time, the operation delay counter is not cleared between adjacent faults and finally the stage will trip. A single transient fault is enough to start the stage and increase the delay counter by 20 ms. For example if the operating time is 140 ms, and the time between two peaks does not exceed the intermittent time setting, then the seventh peak will cause a trip (Figure 5.11-3).

Operation time setting and the actual operation time

When the algorithm detects the direction of the fault outwards from the bus, the stage picks up and the operation delay counter is incremented with 20 ms and a start signal is issued. If the time between successive faults is less than 40 ms, a trip signal is issued when the operation time is full.

When the time between successive faults is more than 40 ms, the stage will release between the faults and the delay counting is restarted from zero for every single fault and no trip will be issued. For such cases the intermittent setting can be used. Figure 5.11-2 shows an example of how the intermittent setting works. The upper start and trip signals are a case with zero intermittent setting. The lower signals are another case with intermittent setting 0.12 s. The operation time setting is 0.14 s in both cases corresponding to seven 20 ms time slots with faults.

The time between the second and the third fault exceeds the release time + intermittent time. Thus the operation delay counter is cleared in both cases: with zero intermittent time and with 0.12 s intermittent time.

The fourth and the next faults do occur after release time but within release time + intermittent time. Thus the operation delay counter is advanced at every fault in the case the intermittent time setting is more than 100 ms (the lower status lines in the figure) and finally a trip signal is issued at t=0.87 s.

When faults do occur more than 20 ms apart each other, every single fault will increment the operation delay counter by 20 ms. In this example the actual operation time starting from the third fault will be 617 ms although, the setting was 140 ms. In case the intermittent setting would have been 0.2 s or more, the two first faults had been included and a trip would have issued at t=0.64 s.

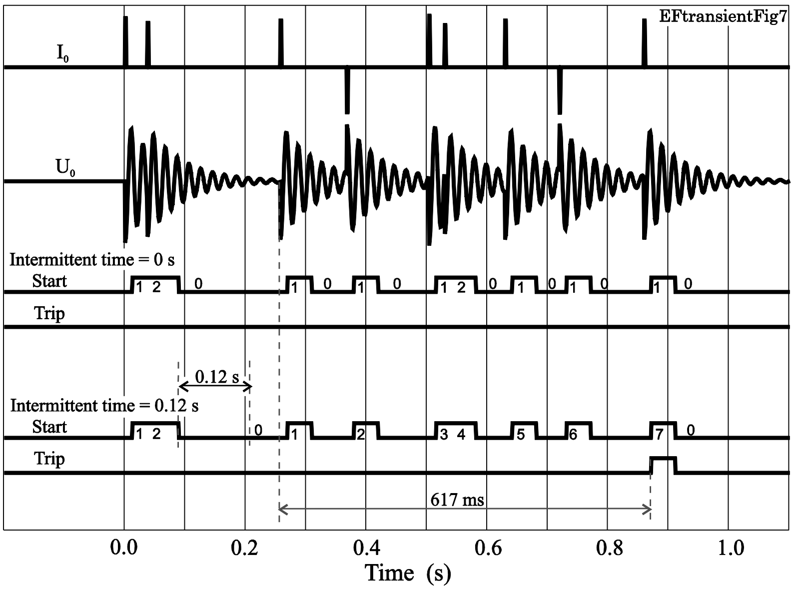


Figure 5.11-2. Effect of the intermittent time parameter. The operation delay setting is 0.14 s = 7x20 ms. The upper start and trip status lines are for a case with the intermittent time set to zero. No trip will happen. The lower start and trip status lines show another case with intermittent time setting 0.12 s. In this case a trip signal will be issued at t=0.87 s.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

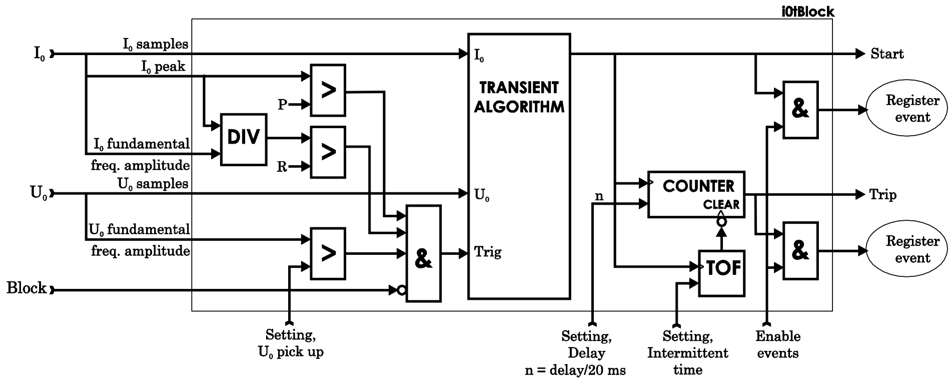


Figure 5.11-3. Block diagram of the directional intermittent transient earth fault stage I_{0INT}>.

Parameters of the directional intermittent transient earth fault stage I_{0INT}> (67NI)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	- DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset after a five minute timeout.	Set
Io1 Io2		pu	The detected I_0 value according the parameter "Input" below.	
Uo		%	The measured U_0 value. U_{0N} = 100 %	
Uo>		%	U_0 pick up level. U_{0n} = 100 %	Set
t>		s	Operation time. Actually the number of cycles including faults x 20 ms. When the time between faults exceeds 20 ms, the actual operation time will be longer.	Set
Io input	Io1Peak Io2Peak		I_{01} Connectors X1-7&8 I_{02} Connectors X1-9&10	Set
Intrmt		s	Intermittent time. When the next fault occurs within this time, the delay counting continues from the previous value.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero
F = Editable when force flag is on

Recorded values of the latest eight faults

There is detailed information available of the eight latest detected faults: Time stamp, U_0 voltage, elapsed delay and setting group.

Recorded values of the directional intermittent transient earth fault stage (8 latest faults) I_{0INT}> (67NI)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		pu	Maximum detected earth fault current
EDly		%	Elapsed time of the operating time setting. 100% = trip
Uo		%	Max. U_0 voltage during the fault
SetGrp	1 2		Active setting group during fault

5.12. Overvoltage protection U> (59)

The overvoltage function measures the fundamental frequency component of the line-to-line voltages regardless of the voltage measurement mode (chapter 7.6). By using line-to-line voltages any phase-to-ground over-voltages during earth faults have no effect. (The earth fault protection functions will take care of earth faults.) Whenever any of these three line-to-line voltages exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

In rigidly earthed 4-wire networks with loads between phase and neutral overvoltage protection may be needed for phase-to-ground voltages, too. In such applications the programmable stages can be used. See chapter 5.27.

Three independent stages

There are three separately adjustable stages: U>, U>> and U>>>. All the stages can be configured for definite time (DT) operation characteristic.

Configurable release delay

The U> stage has a settable release delay, which enables detecting intermittent faults. This means that the time counter of the protection function does not reset immediately after the fault is cleared, but resets after the release delay has elapsed. If the fault appears again before the release delay time has elapsed, the delay counter continues from the previous value. This means that the function will eventually trip if faults are occurring often enough.

Configurable hysteresis

The dead band is 3 % by default. It means that an overvoltage fault is regarded as a fault until the voltage drops below 97 % of the pick up setting. In a sensitive alarm application a smaller hysteresis is needed. For example if the pick up setting is about only 2 % above the normal voltage level, hysteresis must be less than 2 %. Otherwise the stage will not release after fault.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Figure 5.12-1 shows the functional block diagram of the overvoltage function stages U>, U>> and U>>>.

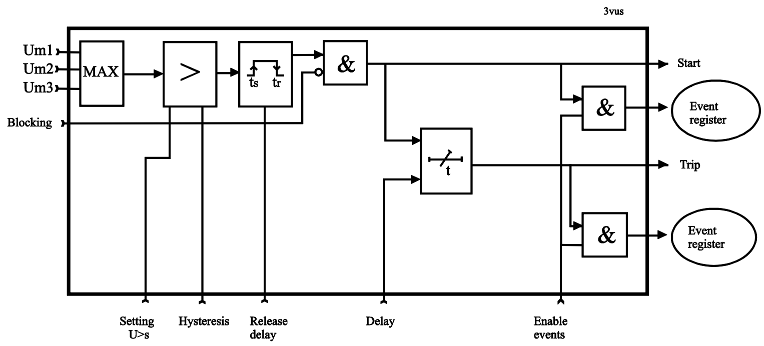


Figure 5.12-1 Block diagram of the three-phase overvoltage stages U>, U>> and U>>>.

Parameters of the overvoltage stages U>, U>>, U>>> (59)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Umax		V	The supervised value. Max. of U12, U23 and U31	
U>, U>>, U>>>		V	Pick-up value scaled to primary value	
U>, U>>, U>>>		%Un	Pick-up setting relative to U_{GN}	Set
t>, t>>, t>>>		s	Definite operation time	Set
RlsDly		s	Release delay (U> stage only)	Set
Hyster	3 (default)	%	Dead band size i.e. hysteresis	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault voltage, elapsed delay and setting group.

Recorded values of the overvoltage stages (8 latest faults) U>, U>>, U>>> (59)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%Un	Maximum fault voltage
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.13. Volts/hertz over-excitation protection U_f> (24)

The saturation of any inductive network components like transformers, inductors, motors and generators, depend on the voltage and frequency. The lower the frequency, the lower is the voltage at which the saturation begins.

The volts/hertz over-excitation protection stage is sensitive to the voltage/frequency ratio instead of voltage only. Figure 5.13-1 shows the difference between volts/hertz and a standard overvoltage function. The maximum of the three line-to-line voltage is used regardless of the voltage measurement mode (chapter 7.6). By using line-to-line voltages any phase-to-ground over-voltages during earth faults have no effect. (The earth fault protection functions will take care of earth faults.)

The used net frequency is automatically adopted according the local network frequency.

Overexcitation protection is needed for generators, which are excitated even during start up and shut down. If such a generator is connected to a unit transformer, also the unit transformer needs volts/hertz over-excitation protection. Another application is sensitive overvoltage protection of modern transformers with no flux density margin in networks with unstable frequency.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

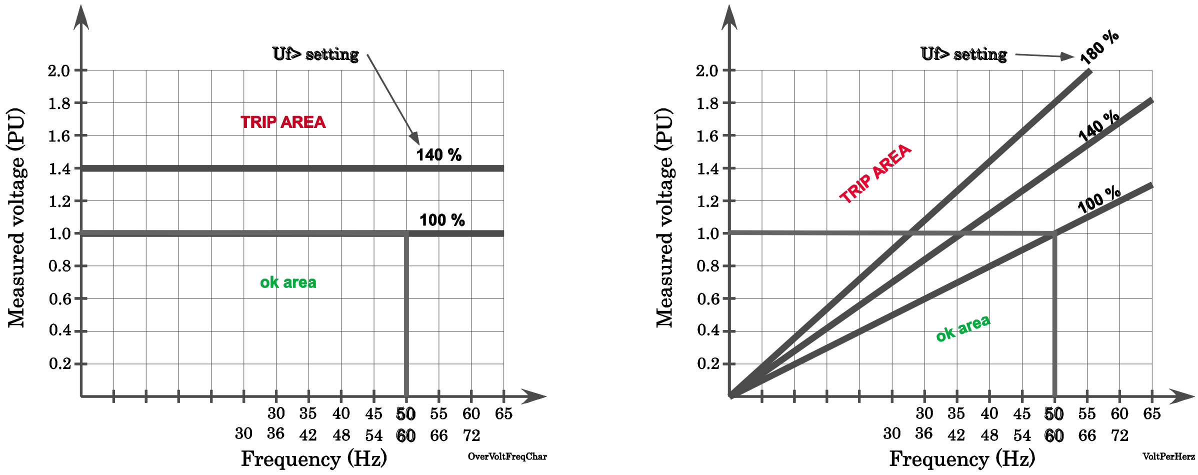


Figure 5.13-1 This figure shows the difference between volts/hertz and normal overvoltage protection. The volts/hertz characteristics on the left depend on the frequency while the standard overvoltage function on the right is insensitive to frequency. The network frequency, 50 Hz or 60 Hz, is automatically adopted by the relay.

The setting for a certain V/Hz value K can be calculated using the following formala

$$U_{fSET} = K \cdot \frac{f_N}{VT_{SEC}} \cdot 100\%.$$

where

U_{fSET} = setting in per cent
K = secondary volts per hertz sensitivity
f_N = rated network frequency
VT_{SEC} = rated secondary of the voltage transformer

Example:

K = 2.56 V_{SEC}/Hz
f_N = 50 Hz
VT_{SEC} = 110 V

$$U_{fSET} = 2.56 \cdot \frac{50}{110} \cdot 100\% = 116\%$$

Parameters of the volts/hertz over-excitation stage U_f> (24)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	- DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Umax		V	The supervised value. Max. of U12, U23 and U31	
f		Hz	The supervised frequency value	
U/f		%	Calculated Umax/f	
Uf>		%	Pick-up setting	Set
t>		s	Definite operation time	Set

For details of setting ranges see chapter 12.3.
Set = An editable parameter (password needed)
C = Can be cleared to zero
F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault voltage, fault frequency, elapsed delay and setting group.

Recorded values of the volts/hertz over-excitation stage U_f> (8 latest faults) U_f> (24)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%	Fault value V/Hz
U		%Un	Fault voltage
f		Hz	Fault frequency
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.14. Undervoltage protection U_1< (27P)

This a special undervoltage protection for generator applications, where the voltage is measured at the generator side of the generator circuit breaker. There are special self blocking features for starting up and shutting down a generator.

This undervoltage function measures the positive sequence of fundamental frequency component U_1 of the measured voltages (for calculation of U_1 see chapter 7.9). By using positive sequence all the three phases are supervised with one value and in case the generator looses connection to the network (loss of mains), the undervoltage situation is detected faster than by using just the minimum of the three line-to-line voltages.

Whenever the positive sequence voltage U_1 drops below the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Blocking during VT fuse failure

As all the protection stages the undervoltage function can be blocked with any internal or external signal using the block matrix. For example if the secondary voltage of one of the measuring transformers disappears because of a fuse failure (See VT supervision function in chapter6.7). The blocking signal can also be a signal from the user's logic (see chapter 8.7).

Self blocking at very low voltage

The stages will be blocked when the voltage is below a separate low voltage blocking setting. With this setting, LVBlk, both stages are blocked, when the voltage U_1 drops below the given limit. The idea is to avoid purposeless alarms, when the generator is not running. The LVBlk setting is common for both stages. The self blocking can not be disabled.

Initial self blocking

When the voltage U_1 has been below the block limit, the stages will be blocked until the pick-up setting has been reached.

Figure 5.14-1 shows an example of low voltage self blocking.

- A The positive sequence voltage U_1 is below the block limit. This is not regarded as an under voltage situation.
- B The positive sequence voltage U_1 is above the block limit but below the pick-up level. However, this is not regarded as an under voltage situation, because the voltage has never been above the pick-up level since being below the block limit.
- C Voltage is OK, because it is above the pick-up limit.
- D This is an under voltage situation.
- E Voltage is OK.
- F This is an under voltage situation.
- G Voltage is under block limit and this is not regarded as an under voltage situation.
- H Same as B.
- I Voltage is OK.
- J Same as G
- K Voltage is OK.

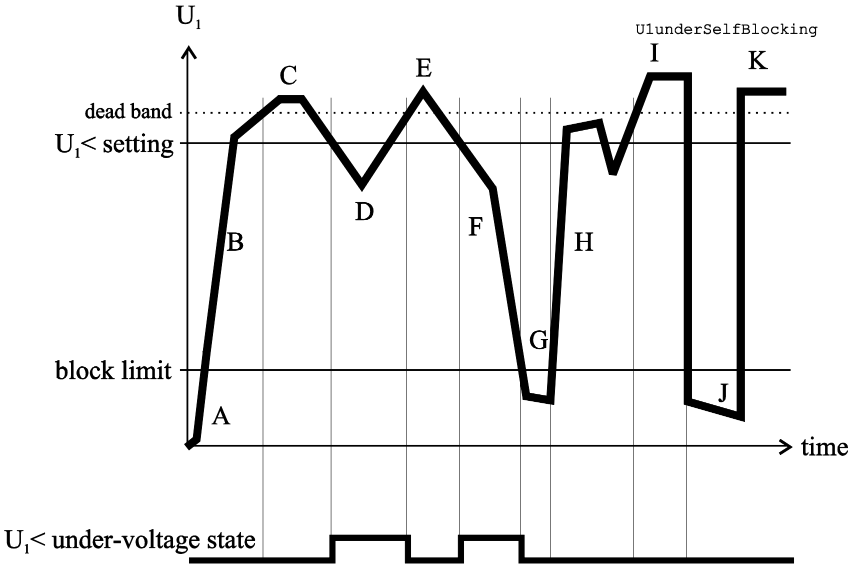


Figure 5.14-1 Positive sequence under voltage state and block limit.

Temporary self blocking at very low currents

Further the pick up can be delayed by using setting I<Blk. When the maximum of the three measured phase currents is less than 1 % of the rated generator current, this delay is enabled. The idea is to avoid purposeless alarms, when the generator circuit breaker is open and the excitation is switched off. By setting the delay equal to zero, this feature is disabled.

Two independent stages

There are two separately adjustable stages: U_1< and U_1<<. Both stages can be configured for definite time (DT) operation characteristic.

Setting groups

There are two settings groups available for both stages. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the under voltage stages U_1<, U_1<< (27P)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
U1		V	The supervised positive sequence voltage in primary volts	
U1		%	The supervised positive sequence voltage of Un/√3	
U1<, U1<<		V	Pick-up value scaled to primary value	
U1<, U1<<		%	Pick-up setting of Un/√3	Set
t<, t<<		s	Definite operation time	Set
LVBlk		%Un	Low limit for self blocking. This is a common setting for both stages.	Set
I<Blk		s	Pick up delay, when current is less than 1 $\%I_{GN}$.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault voltage, elapsed delay and setting group.

Recorded values of the undervoltage stages (8 latest faults) U_1<, U_1<< (27P)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%Un	Minimum fault voltage
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.15. Undervoltage protection U< (27)

This a basic undervoltage protection. The function measures the three line-to-line voltages and whenever the smallest of them drops below the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Blocking during VT fuse failure

As all the protection stages the undervoltage function can be blocked with any internal or external signal using the block matrix. For example if the secondary voltage of one of the measuring transformers disappears because of a fuse failure (See VT supervision function in chapter 6.7). The blocking signal can also be a signal from the user's logic (see chapter 8.7).

Self blocking at very low voltage

The stages can be blocked with a separate low limit setting. With this setting, the particular stage will be blocked, when the biggest of the three line-to-line voltages drops below the given limit. The idea is to avoid purposeless tripping, when voltage is switched off. If the operating time is less than 0.08 s, the blocking level setting should not be less than 15 % to the blocking action to be enough fast. The self blocking can be disabled by setting the low voltage block limit equal to zero.

Figure 5.15-1 shows an example of low voltage self blocking.

- A The maximum of the three line-to-line voltages U_{LLmax} is below the block limit. This is not regarded as an under voltage situation.
- B The voltage U_{LLmin} is above the block limit but below the pick-up level. This is an undervoltage situation.
- C Voltage is OK, because it is above the pick-up limit.
- D This is an under voltage situation.
- E Voltage is OK.
- F This is an under voltage situation.
- G The voltage U_{LLmin} is under block limit and this is not regarded as an under voltage situation.
- H This is an under voltage situation.
- I Voltage is OK.
- J Same as G
- K Voltage is OK.

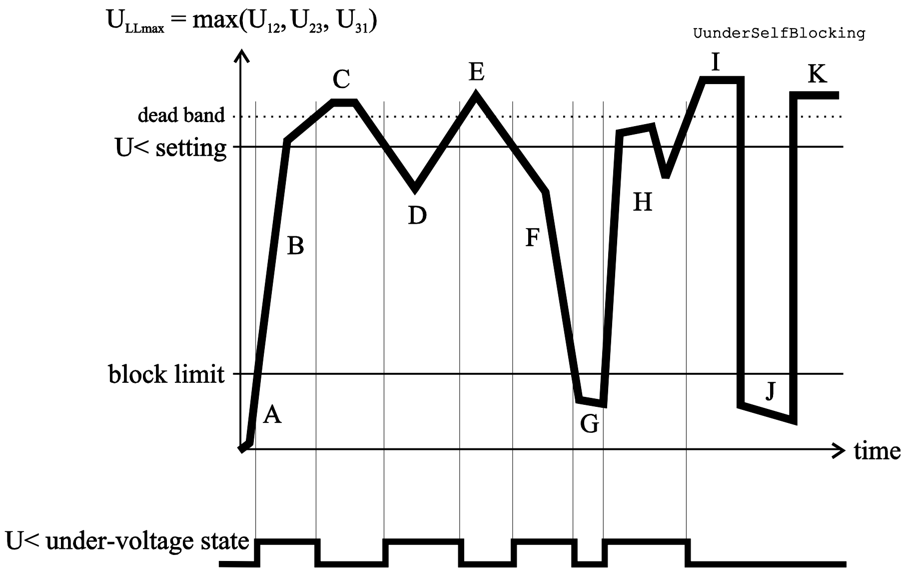


Figure 5.15-1 Under voltage state and block limit.

Three independent stages

There are three separately adjustable stages: U<, U<< and U<<<. All these stages can be configured for definite time (DT) operation characteristic.

Setting groups

There are two settings groups available for all stages. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the under voltage stages U<, U<<, U<<< (27)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	- DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
MinU		V	The supervised minimum of line-to-line voltages in primary volts	
U<, U<<, U<<<		V	Pick-up value scaled to primary value	
U<, U<<, U<<<		%Ugn	Pick-up setting	Set
t<, t<<, t<<<		s	Definite operation time	Set
LVBlk		%Ugn	Low limit for self blocking	Set
RlsDly		s	Release delay (U< stage only)	Set
Hyster	Default 3.0 %	%	Dead band setting	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults for each of the stages: Time stamp, fault voltage, elapsed delay, voltage before the fault and setting group.

Recorded values of the undervoltage stages (8 latest faults) U<, U<<, U<<< (27)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%Ugn	Minimum fault voltage
EDly		%	Elapsed time of the operating time setting. 100% = trip
PreFlt		%Ugn	Supervised value before fault, 1 s average value.
SetGrp	1 2		Active setting group during fault

5.16. Zero sequence voltage protection U_0> (59N)

The zero sequence voltage protection is used as unselective backup for earth faults and also for selective earth fault protections for generators having a unit transformer between the generator and the busbar.

This function is sensitive to the fundamental frequency component of the zero sequence voltage. The attenuation of the third harmonic is more than 60 dB. This is essential, because 3n harmonics exist between the neutral point and earth also when there is no earth fault.

Whenever the measured value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Measuring the zero sequence voltage

The zero sequence voltage is either measured with three voltage transformers (e.g. broken delta connection), one voltage transformer between the generator's neutral point and earth or calculated from the measured phase-to-earth voltages according to the selected voltage measurement mode (see chapter 7.6):

- Phase: the zero sequence voltage is calculated from the phase voltages and therefore a separate zero sequence voltage transformer is not needed. The setting values are relative to the configured voltage transformer (VT) voltage/√3.
- Line+U_0: The zero sequence voltage is measured with voltage transformer(s) for example using a broken delta connection. The setting values are relative to the VT_0 secondary voltage defined in configuration.

NOTE! The U_0 signal must be connected according the connection diagram (Figure 10.2-1) in order to get a correct polarization. Please note that actually the negative U_0, $-U_0$, is to be connected to the relay.

Two independent stages

There are two separately adjustable stages: U_0> and U_0>>. Both stages can be configured for definite time (DT) operation characteristic.

The zero sequence voltage function comprises two separately adjust-table zero sequence voltage stages (stage U_0> and U_0>>).

Setting groups

There are two settings groups available for both stages. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

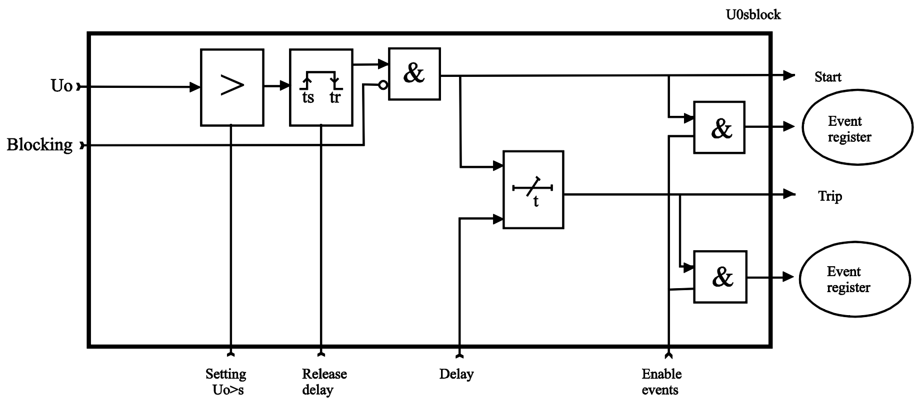


Figure 5.16-1 Block diagram of the zero sequence voltage stages U_0> and U_0>>

Parameters of the residual overvoltage stages $U_0>$, $U_0>>$ (59N)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Uo		%	The supervised value relative to Un/√3	
Uo>, Uo>>		%	Pick-up value relative to Un/√3	Set
t>, t>>		s	Definite operation time	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault voltage, elapsed delay and setting group.

Recorded values of the residual overvoltage stages $U_0>$, $U_0>>$ (59N)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%	Fault voltage relative to Un/√3
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.17. 100% stator earth fault protection U_{0f3}< (64F3)

NOTE! This protection stage is available only in voltage measurement mode "2LL+Uo" (see chapter 7.6).

NOTE! For this function the zero sequence voltage must be measured from the generator's neutral point and the earth.

NOTE! A unit transformer is usually needed between the generator and the busbar for selective operation of this function.

The third harmonic undervoltage stage can be used to detect earth-faults near a high impedance earthed generator's neutral point or even at the neutral point. These kind of faults are rare, but if a second earth-fault would occur in one of the phases the consequences would be severe, because the first earth-fault had made the network solidly earthed. By using the U_{0F3}< stage such situation can be avoided.

Neutral point is a blind point for conventional earth fault function

In case there is an earth-fault near the neutral point or even at the neutral point , the residual current and zero sequence voltage caused by such fault are negligible or even zero. Thus a conventional earth-fault protection based on fundamental frequency I_0 and/or U_0 measurement is not able to detect such faults. On the other hand, faults near the neutral point are rare, because the voltage stress is low.

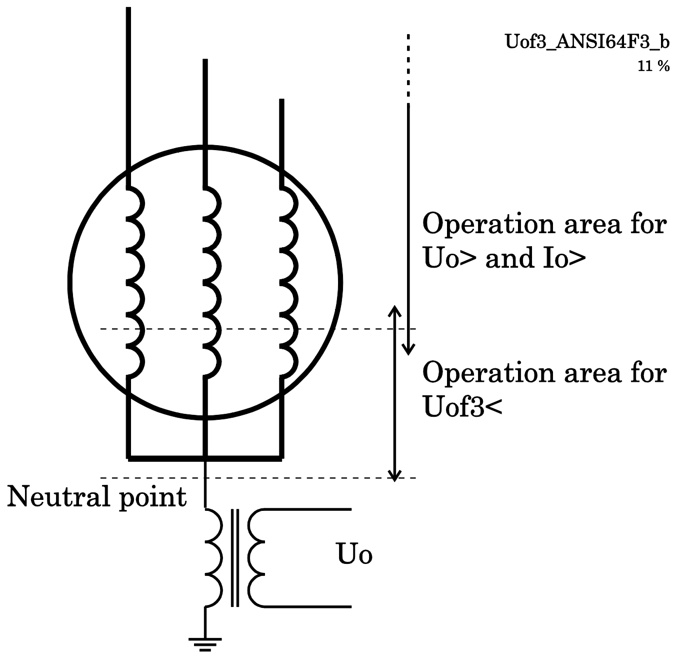


Figure 5.17-1 The overlapping coverage of winding earth-fault protection of basic protection stages and the third harmonic undervoltage protection stage.

100 % coverage of the windings

The "one hundred per cent" in the title is slightly misleading. Actually the 100 % coverage is achieved only when this stage is used together with conventional earth fault protection.

The operation range of fundamental frequency earth-fault functions 59N and 51N covers about 95 % of the stator windings starting from the HV end, but never 100 % of the windings. The coverage of the U_{0f3}< stage is about 10% ... 30 % of the windings but starting from the LV end, i.e. the neutral point. Thus the ranges do overlap as in Figure 5.17-1 and 59N or 51N together with this 64F3 does cover 100 % of the stator windings.

Natural 3rd harmonic at the neutral point

The voltage a generator is not ideal pure sine wave. There will exist some small amount of harmonics as well. At the neutral point there will exists some amount of 3rd, 6th, 9th, 12th ..., i.e. 3n harmonics. The base frequency and other than 3n harmonics in phase voltages do cancel each other at the neutral point (Figure 5.17-2 and Figure 5.17-3). The third harmonic residual undervoltage stage U_{0f3}< is supervising the level of the 3rd harmonic at the neutral point. If there is an earth fault near the neutral point, this 150 Hz or 180 Hz voltage drops below setting and the stage will pick up.

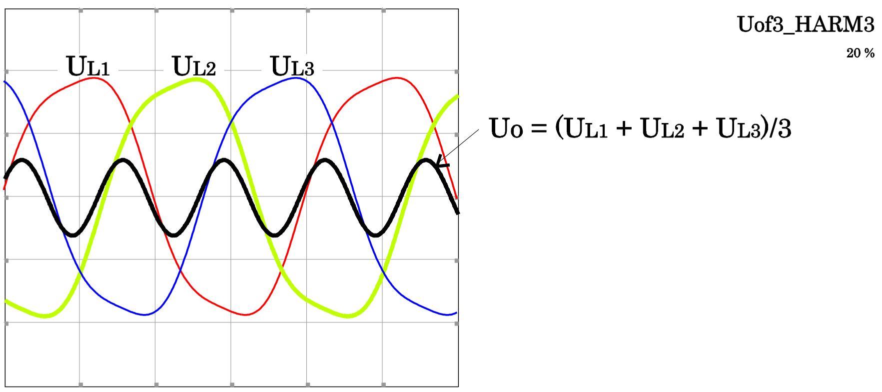


Figure 5.17-2 When symmetric phase-to-ground voltages containing third harmonic are summed together, the result is not zero.

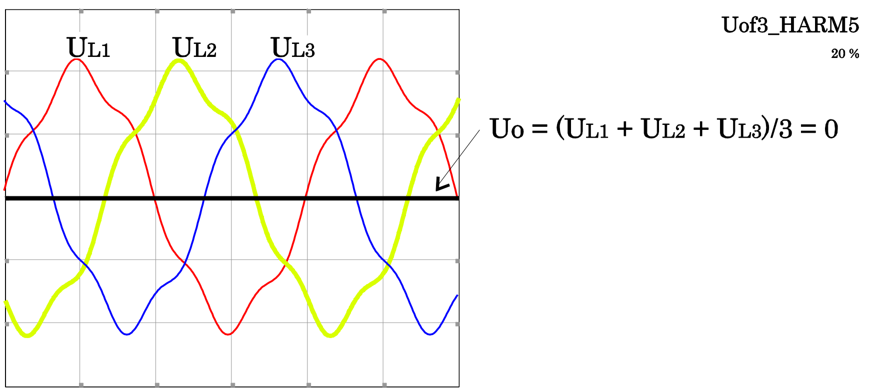


Figure 5.17-3 When the phase-to-ground voltages do contain fifth harmonic, they cancel each other when summed and the resulting zero sequence voltage U_0 will be zero.

Finding out the correct pick-up setting

A problem with this third harmonic undervoltage stage is to find a proper pick-up setting. In practice an empirical value is used, because the natural 3rd harmonic at the neutral point is dependent on:

- Construction of the generator
- Loading and the power factor
- Amount of excitation
- Earthing circuitry
- Transformers connected.

The relay itself can be used to measure the actual level of 3rd U_0 harmonic during various situations. Typically the generator is producing its minimum amount of 3rd harmonic when the load is small and the excitation is low. The pick-up setting must be below this minimum value. A typical operation delay is one minute.

Blocking the protection

The squelch of voltage measurement will block the stage when the generator is stopped. Using the block matrix, blocking by under-voltage, under-power, CB position and other blocking schemes are possible.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the 100 % stator earth fault stage U_{0f3}< (64F3)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Uof3		%	The supervised value relative to U_{0N}. For U_{0N} see chapter 7.2.	
Uof3<		%	Pick-up value relative to U_{0N}. For U_{0N} see chapter 7.2.	Set
t<		min	Definite operation time in minutes	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault voltage, elapsed delay and setting group.

Recorded values of the 100 % stator earth fault stage U_{0f3}< (64F3)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%	3^{rd} harmonic value relative to Un/√3 during fault
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.18. Overfrequency and underfrequency protection f>, f< (81H/81L)

Frequency protection is used for load sharing, loss of mains detection and as a backup protection for over-speeding.

The frequency function measures the frequency from the two first voltage inputs. At least one of these two inputs must have a voltage connected to be able to measure the frequency. Whenever the frequency crosses the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation delay setting, a trip signal is issued. For situations, where no voltage is present an adapted frequency is used. See chapter 4.2.

Protection mode for f>< and f><>< stages

These two stages can be configured either for overfrequency or for underfrequency.

Under voltage self blocking of underfrequency stages

The underfrequency stages are blocked when biggest of the three line-to-line voltages is below the low voltage block limit setting. With this common setting, LVBlk, all stages in underfrequency mode are blocked, when the voltage drops below the given limit. The idea is to avoid purposeless alarms, when the generator is not running.

Initial self blocking of underfrequency stages

When the biggest of the three line-to-line voltages has been below the block limit, the under frequency stages will be blocked until the pick-up setting has been reached.

Four independent frequency stages

There are four separately adjustable frequency stages: f><, f><><, f<, f<<. The two first stages can be configured for either overfrequency or underfrequency usage. So totally four underfrequency stages can be in use simultaneously. Using the programmable stages even more can be implemented (chapter 5.27). All the stages have definite operation time delay (DT).

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the over & under frequency stages f><, f><><, f<, f<< (81H/81L)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
f		Hz	The supervised value.	
 fX fXX f< f<<		Hz	Pick-up value Over/under stage f><. See Mode Over/under stage f><><. Under stage f< Under stage f<<	Set
 tX tXX t< t<<		s	Definite operation time f>< stage f><>< stage f< stage f<< stage	Set
Mode	 > <		Operation mode. (only for f>< and f><><) Overfrequency mode Underfrequency mode	Set
LVblck		%Un	Low limit for self blocking. This is a common setting for all four stages.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, frequency during fault, elapsed delay and setting group.

Recorded values of the over & under frequency stages (8 latest faults) f><, f><><, f<, f<< (81H/81L)

Parameter	Value	Unit	Description

	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		Hz	Faulty frequency
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.19. Rate of change of frequency (ROCOF) protection df/dt (81R)

Rate of change of frequency (ROCOF or df/dt) function is used for fast load shedding, to speed up operation time in over- and under-frequency situations and to detect loss of grid.

A special application for ROCOF is to detect loss of grid (loss of mains, islanding). The more the remaining load of the local generator differs from the load before the loss of grid, the better the ROCOF function detects the situation.

Frequency behaviour during load switching

Load switching and fault situations may generate change in frequency. A load drop will increase the frequency and increasing load will decrease the frequency, at least for a while. The frequency may oscillate after the initial change. After a while the control system of the generator (s) will drive the frequency back to the original value. However, in case of a heavy short circuit fault or in case the new load exceeds the generating capacity, the average frequency keeps on decreasing.

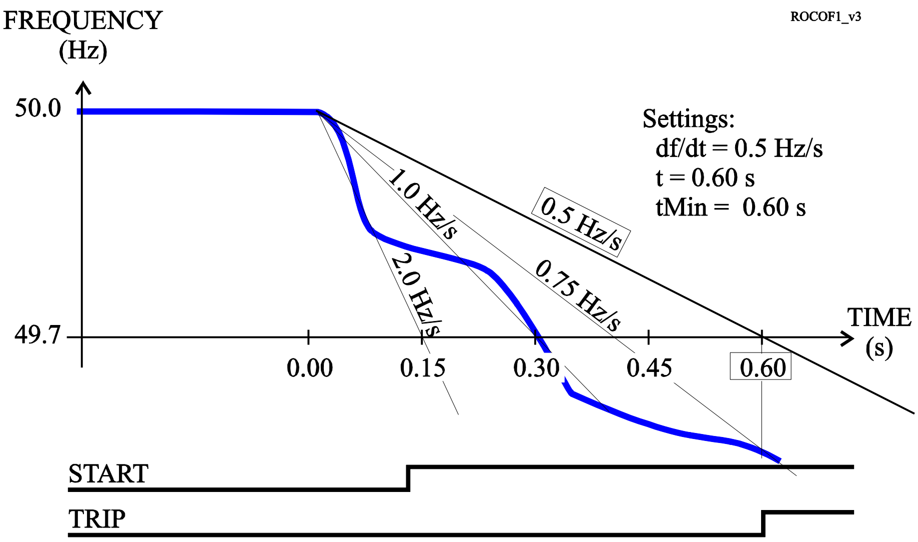


Figure 5.19-1 An example of definite time df/dt operation time. At 0.6 s, which is the delay setting, the average slope exceeds the setting 0.5 Hz/s and a trip signal is generated.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Description of ROCOF implementation

The ROCOF function is sensitive to the absolute average value of the time derivate of the measured frequency |df/dt|. Whenever the measured frequency slope |df/dt| exceeds the setting value for 80 ms time, the ROCOF stage picks up and issues a start signal after an additional 60 ms delay. If the average |df/dt|, since the pick-up moment, still exceeds the setting, when the operation delay time has elapsed, a trip signal is issued. In this definite time mode the second delay

parameter "minimum delay, t_{Min}" must be equal to the operation delay parameter "t".

If the frequency is stable for about 80 ms and the time t has already elapsed without a trip, the stage will release.

ROCOF and over/under frequency stages

One difference between over-/under-frequency and df/dt function is the speed. In many cases a df/dt function can predict an overfrequency or underfrequency situation and is thus faster than a simple overfrequency or underfrequency function. However, in most cases a standard overfrequency and underfrequency stages must be used together with ROCOF to ensure tripping also in case the frequency drift is slower than the slope setting of ROCOF.

Definite operation time characteristics

Figure 5.19-1 shows an example where the df/dt pick-up value is 0.5 Hz/s and the delay settings are t=0.60 s and t_{Min}=0.60 s. Equal times t == t_{Min} will give a definite time delay characteristics. Although the frequency slope fluctuates the stage will not release but continues to calculate the average slope since the initial pick-up. At the defined operation time, t = 0.6 s, the average slope is 0.75 Hz/s. This exceeds the setting, and the stage will trip.

At slope settings less than 0.7 Hz/s the fastest possible operation time is limited according the Figure 5.19-2.

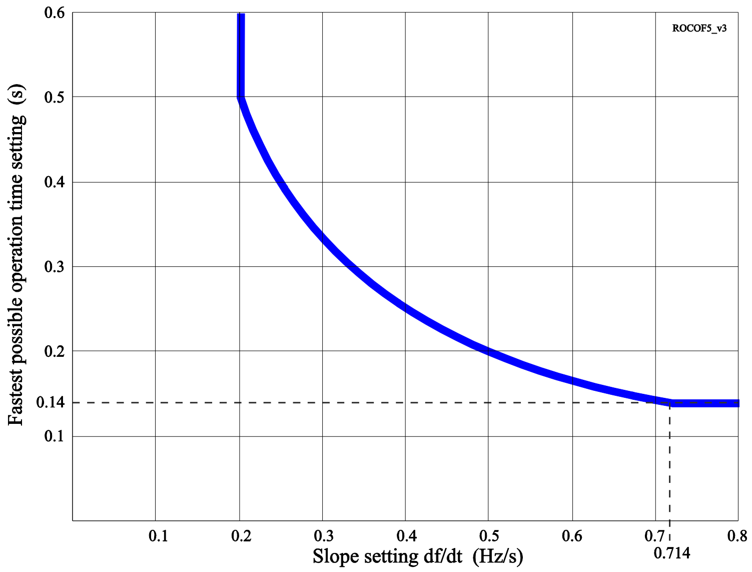


Figure 5.19-2 At very sensitive slope settings the fastest possible operation time is limited according the figure.

Inverse operation time characteristics

By setting the second delay parameter t_{Min} smaller than the operational delay t, an inverse type of operation time characteristics is achieved.

Figure 5.19-3 shows three examples, where the frequency behaviour is the same as in the first example, but the t_{Min} setting is 0.15 s instead of being equal with t. The operation time depends of the measured average slope according the following equation

$$t_{TRIP} = \frac{s_{SET} \cdot t_{SET}}{|s|}$$ where,

t_{TRIP}	=	Resulting operation time (seconds).
s_{SET}	=	df/dt i.e. slope setting (hertz/seconds).
t_{SET}	=	Operation time setting t (seconds).
s	=	Measured average frequency slope (hertz/seconds).

The minimum operation time is always limited by the setting parameter t_{Min}. In the example of the fastest operation time, 0.15 s, is achieved when the slope is 2 Hz/s or more. The leftmost curve in Figure 5.19-3 shows the inverse characteristics with the same settings as in Figure 5.19-4.

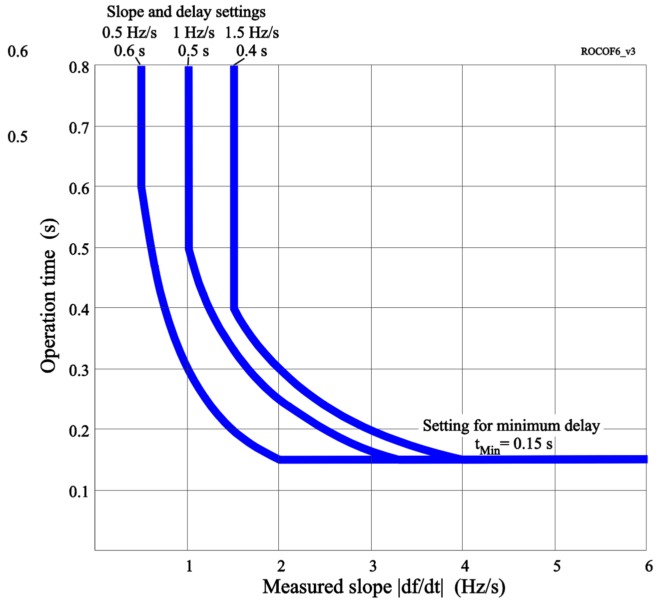


Figure 5.19-3 Three examples of possible inverse df/dt operation time characteristics. The slope and operation delay settings define the knee points on the left. A common setting for t_{Min} has been used in these three examples. This minimum delay parameter defines the knee point positions on the right.

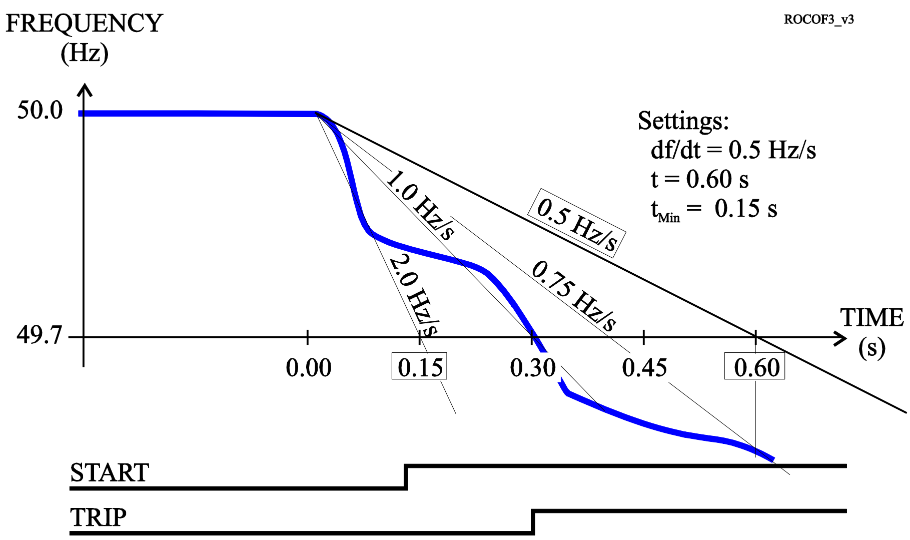


Figure 5.19-4 An example of inverse df/dt operation time. The time to trip will be 0.3 s, although the setting is 0.6 s, because the average slope 1 Hz/s is steeper than the setting value 0.5 Hz/s.

Parameters of the rate of change of frequency stage df/dt> (81R)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
f		Hz	Measured frequency	
df/dt		Hz/s	The supervised value	
df/dt>		Hz/s	Pick-up value	Set
t>		s	Definite operation time	Set
tMin>		s	Minimum operating time for inverse delay. For definite time set tMin = t	Set
LVblk		%Un	Low limit for self blocking. This is a common setting for all four stages and with the undervoltage stages.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, frequency drift, elapsed delay and setting group.

Recorded values of the rate of change of frequency stage (8 latest faults) df/dt> (81R)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		Hz/s	Faulty frequency drift
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.20. Under-impedance protection Z< (21)

Under-impedance protection can be used to detect near short circuit faults, even when excitation of the generator collapse thus limiting the available short circuit current. It is an alternative for the voltage restrained overcurrent protection (chapter 5.6). When the generator's short circuit current capacity is limited any high set overcurrent stage might not pick-up, but an under-impedance stage will still detect the fault.

The stage is sensitive to positive sequence impedance Z_1, which is calculated using the equation

$Z_1 = \frac{U_1}{I_1}$, where

Z_1 = absolute value of positive sequence impedance.

U_1 = positive sequence voltage

I_1 = positive sequence current.

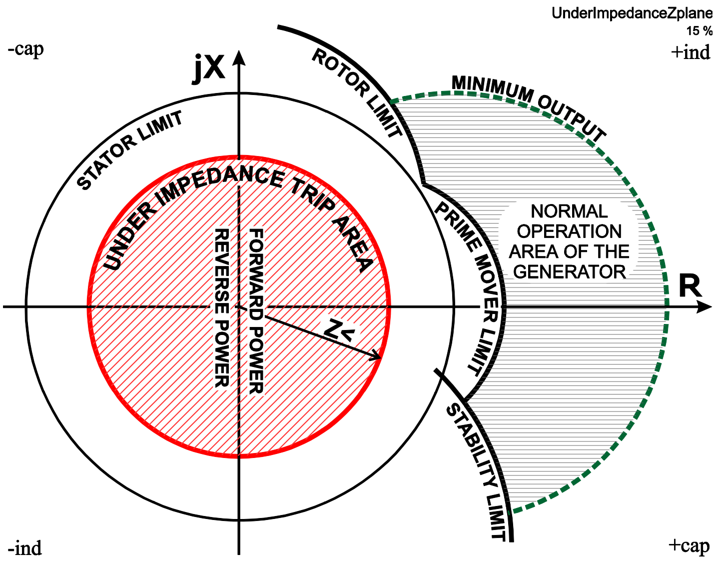


Figure 5.20-1 The trip region of under-impedance stage is a circle in origin. The radius Z< is the setting value. The bigger circle "stator limit" represents the rated power of the generator.

The impedance relay is insensitive to the phase angle between current and voltage. Its characteristics in an impedance plane is a circle in origin, where the horizontal axis represents resistance R and the vertical axis represents reactance jX (Figure 5.20-1).

Whenever the positive sequence impedance goes inside the circle, the stage will pick-up. The radius Z< of the circle and the definite delay time are the setting parameters.

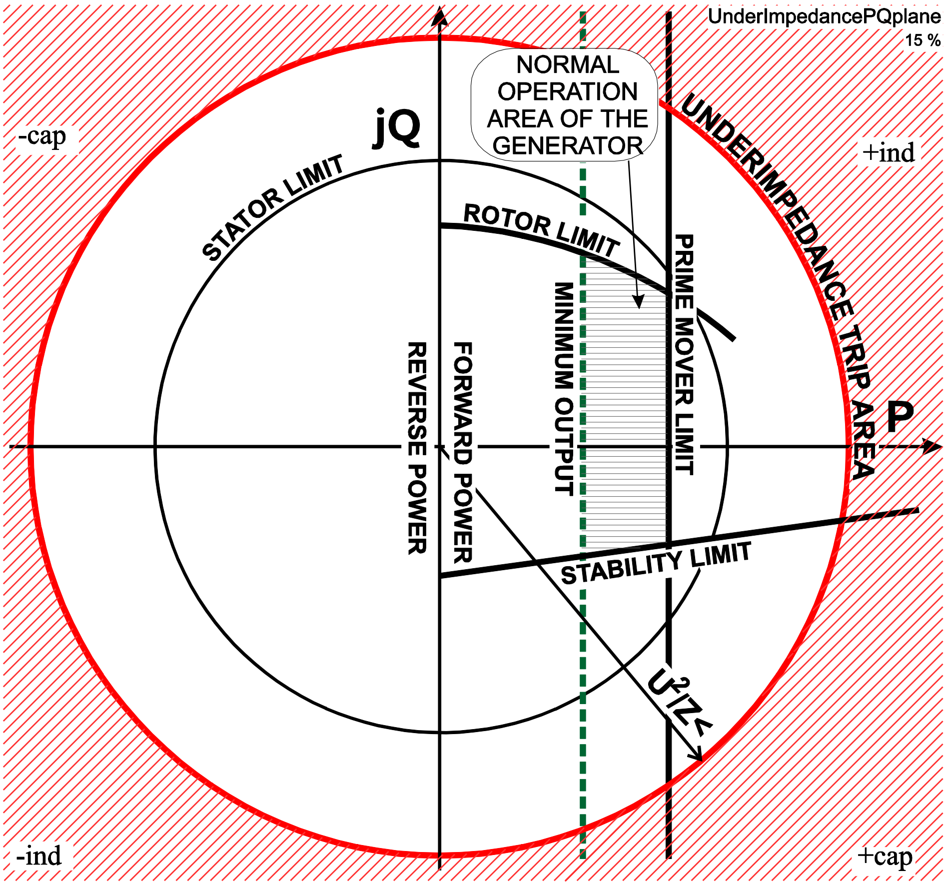


Figure 5.20-2 Underimpedance characteristics drawn in power plane assuming, that voltage is constant. The trip area is now outside of the circle having radius $U^2/Z<$, where Z< is the pick-up setting.

Undercurrent blocking

When for some reason voltage collapses but currents remain at normal load levels, the calculated impedance may fall into the trip area. Inverted start signal from the most sensitive overcurrent stage can be used to block the under-impedance stages during abnormal voltages not caused be short circuit faults.

Characteristic on a PQ-power plane

In Figure 5.20-2 the same characteristics as in the previous figure is drawn on a PQ-power plane assuming a constant voltage of 1 PU. The transformation is $\underline{S} = U^2/Z^*$, where U is the voltage and Z^* is the complex conjugate of impedance Z.

The borderline of under-impedance trip area in the power plane is still a circle in origin, but now the trip area is the outside of the circle. The shape of the normal operation area is totally different. For example the maximum active power (prime mover limit) is just a vertical line while in impedance plane (Figure 5.20-1) it is a circle touching the jX axis.

When current is zero the impedance calculation gives infinite as result. Thus the stage will not pick-up in a machine stand still situation.

Two independent under-impedance stages

There are two separately adjustable stages available: Z< and Z<<.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the under-impedance stages Z<, Z<< (21)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Z		ohm	The supervised value scaled to primary value. "Inf" = infinite	
Z		xZn	The supervised value scaled to per unit (pu). 1 pu = $1xZ_n = U_{gn}/(\sqrt{3}xI_{gn})$. "Inf" = infinite	
Z< Z<<		ohm	Pick-up value scaled to primary value	
Z< Z<<		xZn	Pick-up setting in per unit (pu). 1 pu = $1xZ_n = U_{gn}/(\sqrt{3}xI_{gn})$.	Set
t<		s	Definite operation time	Set
U1		V	Measured value of positive sequence voltage U_1	
I1		A	Measured value of positive sequence current I_1	

For details of setting ranges see chapter 12.3.

Set = An editable value (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest earth faults: Time stamp, fault impedance, elapsed delay and setting group.

Recorded values of the under-impedance stages Z<, Z<< (21)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		Zn	Minimum fault impedance
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.21. Under-excitation protection Q< (40)

Synchronous machines need some minimum level of excitation to remain stable throughout their load range. If excitation is too low, the machine may drop out of synchronism. The under-excitation protection protects the generator against the risk of lost of synchronism.

When the generator produces capacitive power, that is when the reactive component of the power phasor is negative, the excitation current can be so low, that the synchronism is lost.

This stage supervises the amount of capacitive power and in case it exceeds the setting a start signal is issued. If the fault continues longer than user's operation delay time setting, a trip signal is issued.

The measurement of the degree of excitation is based on a complex three-phase power vector, which is calculated from the fundamental components of the phase currents and line-to-line voltages.

Trip area on a PQ-plane

The tripping area of the under-excitation stage on a PQ-plane is defined with two parameters, Q1 and Q2, see Figure 5.21-1 and Figure 5.21-2. When the tip of the power phasor lies on the left side of the left side of a straight line drawn through Q1 and Q2 and on the negative side of P-axis , the stage picks up.

The P coordinate of the setting point Q1 has a fixed value equal to zero and the Q coordinate is adjustable.

The P coordinate of the setting point Q2 has a fixed value of 80% of the rated power of the generator and the Q coordinate is adjustable.

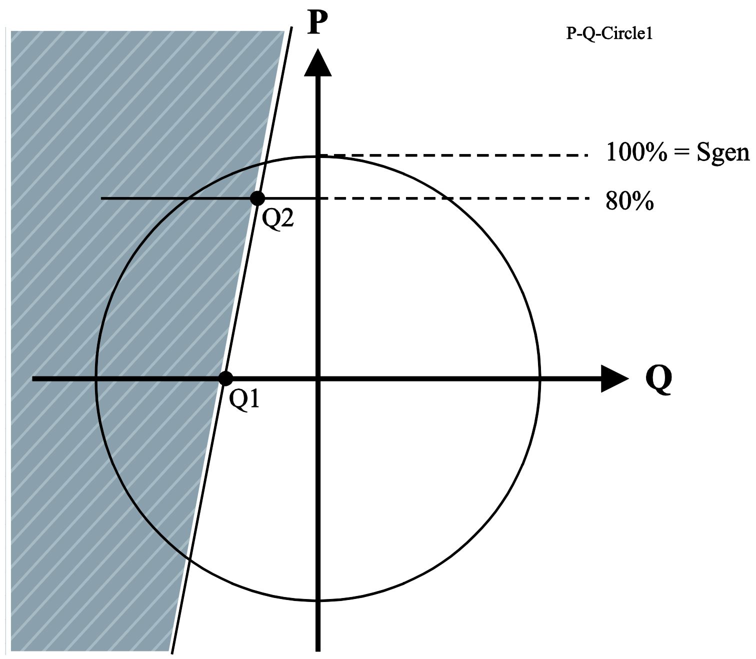


Figure 5.21-1 Setting of the under-excitation stage by means of the par-meters Q1 and Q2. The shaded area is the area of operation. In this example the operation depends on both P and Q, because the operating line has an 8° slope (Q1 - Q2 = 14%).

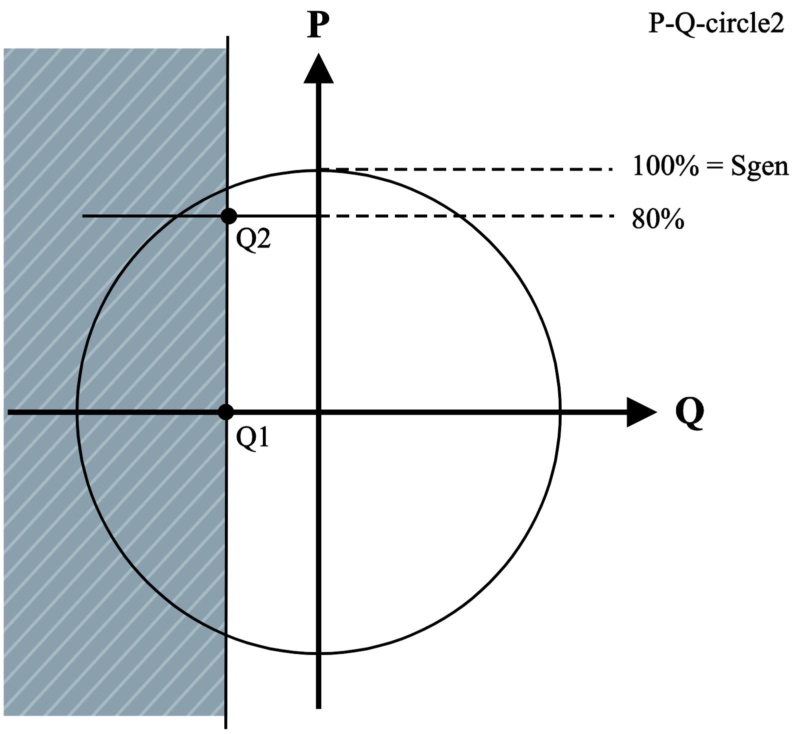


Figure 5.21-2 Setting of the under-excitation stage by means of the parameters Q1 and Q2. The shaded area constitutes the area of operation. In the above example the operation solely depends on the reactive power, because the operating line is vertical (Q1 - Q2 = 0%).

Power swing

A release time setting is available against prolonged power swings. In a power swing situation the power phasor is swinging back and forth between capacitive and inductive power. With a long enough release time setting the stage accumulates the total fault time and will eventually trip.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the under-excitation stage Q< (40)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
P		%Sgn	The supervised active power value.	
Q		%Sgn	The supervised reactive power value.	
Q@P0%		%Sgn kvar	Setting 1. See Figure 5.21-1	Set
Q@P80%		%Sgn kvar	Setting 2. See Figure 5.21-2	Set
t<		s	Definite operation time	Set
RlsDly		s	Release delay for power swing	Set

For details of setting ranges see chapter 12.3.

Set = An editable value (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest earth faults: Time stamp, fault power P and Q, elapsed delay and setting group.

Recorded values of the under-excitation stage Q< (40)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
P		%Sgn	Active fault power
Q		%Sgn	Reactive fault power
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.22. Under-reactance and loss of excitation protection X< (40)

Synchronous machines need some minimum level of excitation to remain stable throughout their load range. If excitation is lost or is too low, the machine may drop out of synchronism. The loss of excitation stages X< and X<<, are used to supervise that the synchronous machine is working in the stable area.

The protection is based on positive sequence impedance as viewed from the machine terminals. This impedance is calculated using the measured three phase voltages and phase currents according the following equation:

$$\overline{Z}_1 = \frac{\overline{U}_1}{\overline{I}_1}$$, where

Z_1 = positive sequence impedance.

U_1 = positive sequence voltage phasor

I_1 = positive sequence current phasor.

If this impedance goes under the steady state stability limit, the synchronous machine may loose its stability and drop out of synchronism.

Detecting power swinging

A release time setting is available against prolonged power swings. In a power swing situation the power phasor is swinging back and forth between capacitive and inductive power. With a long enough release time setting the stage accumulates the total fault time and will eventually trip.

Undercurrent blocking

When for some reason voltage collapses but currents remain at normal load levels, the calculated impedance may fall into the trip area. Inverted start signal from the most sensitive overcurrent stage can be used to block the under-reactance stages during abnormal voltages not caused be short circuit faults.

Characteristic on an impedance plane

The characteristics on an impedance plane is a circle covering the unstable area of the synchronous machine (Figure 5.22-1). The

radius X< and centre point [Roffset, Xoffset] of the circle are editable. Whenever the positive sequence impedance goes inside this circle, the stage will pick-up. If the fault stays on longer than the definite time delay setting, the stage will issue a trip signal.

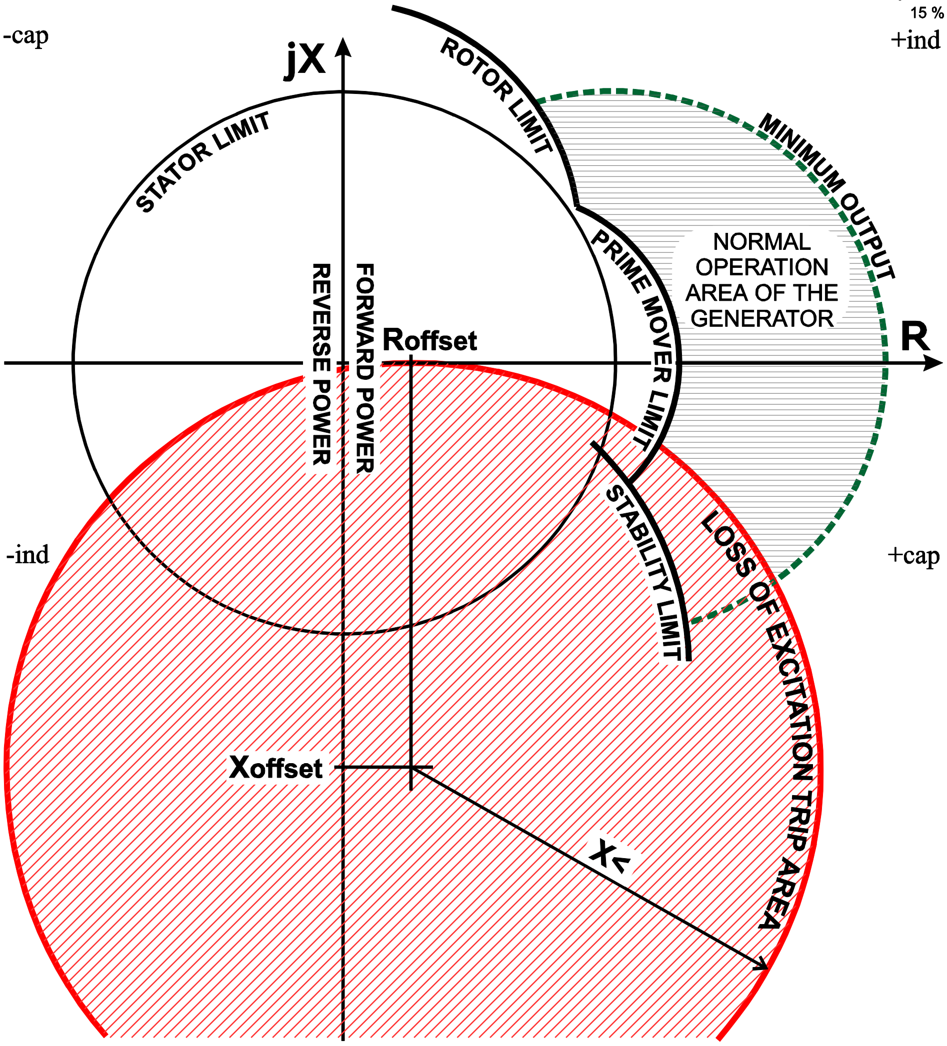


Figure 5.22-1 The trip region of loss of excitation stage is a circle is covering the unstable area of the generator. The radius X<, Roffset and Xoffset are the setting parameters. Whenever the positive sequence impedance falls inside the X< circle, the stage picks up.

Calculating setting values

The machine manufacturer specifies:

X_d = synchronous unsaturated reactance and the

X'_d = transient reactance for the synchronous machine.

The settings for loss of excitation stages can be derived from these machine parameters, but there are many practices to do it. Here is one:

Radius of the circle $X< \; = X_d/2$

Resistive offset $Ros = 0.14\ (X'_d + X_d/2)$

Reactive offset $Xos = -(X'_d + X_d/2)$

All the settings are in per unit.

$$X_{PU} = \frac{X}{Z_N}$$, where

X_{PU} = Reactance (or resistance) per unit
X = Reactance (or resistance) in ohms
Z_N = Nominal impedance of the machine

$$Z_N = \frac{U_N^2}{S_N}$$, where

Z_N = Nominal impedance of the machine
U_N = Nominal voltage of the machine
S_N = Nominal power of the machine

Characteristic on power plane

In Figure 5.22-2 the same characteristics as in the previous figure is drawn on a PQ-power plane assuming a constant voltage of 1 PU. The transformation is $\underline{S} = U^2/Z^*$, where U is the voltage and Z^* is the complex conjugate of impedance Z.

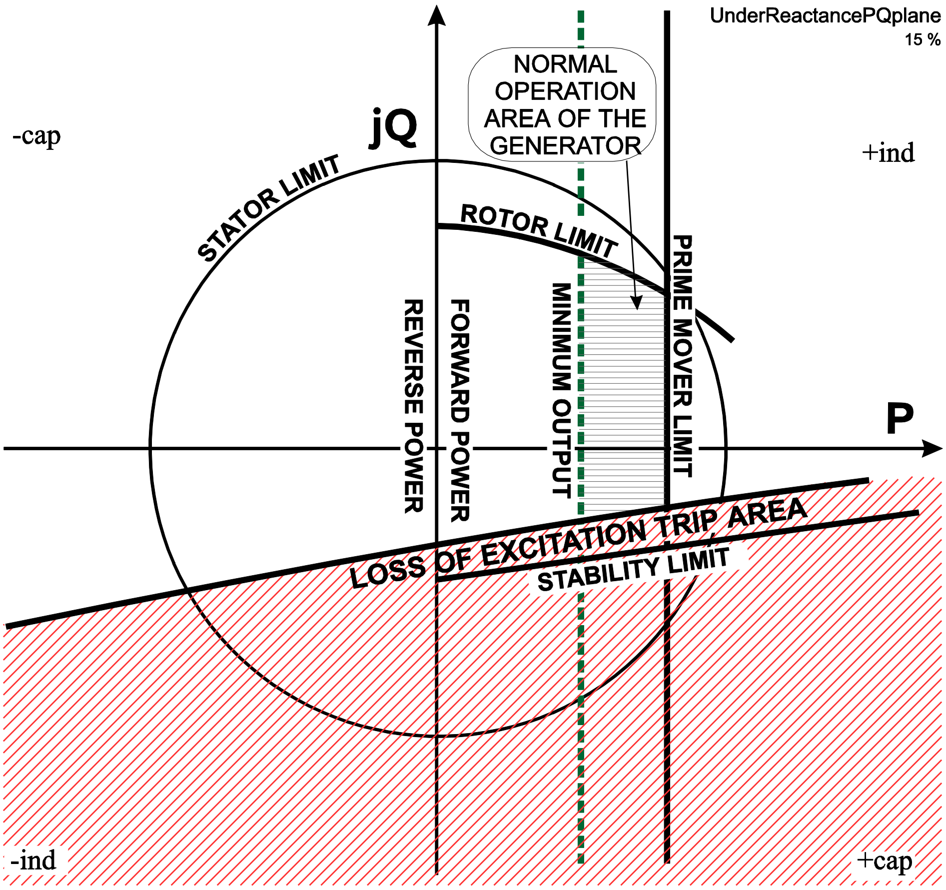


Figure 5.22-2 The loss of excitation characteristics drawn on a power plane.

Two independent under-reactance stages

There are two separately adjustable stages available: X< and X<<.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

Parameters of the under-reactance stages X<, X<< (40)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Z		ohm	The supervised value scaled to primary value. "Inf" = infinite	
Z		xZn	The supervised value scaled to per unit (pu). 1 pu = $1xZ_N = U_{GN}/(\sqrt{3}xI_{GN})$. "Inf" = infinite	
Zφ		°	Angle of the supervised impedance	
X< X<<		ohm	Pick-up value scaled to primary value	
X< X<<		xZn	Pick-up setting in per unit (pu). 1 pu = $1xZ_n = U_{GN}/(\sqrt{3}xI_{gn})$.	Set
t<		s	Definite operation time	Set
RlsDly		s	Release delay	Set
Ros		xZn	Resistive offset for trip area origin in pu.	Set
Xos		xZn	Reactive offset for trip area origin in pu.	Set
Ros		ohm	Resistive offset for trip area origin in primary ohms.	
Xos		xZn	Reactive offset for trip area origin in primary ohms.	

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest earth faults: Time stamp, fault impedance, fault angle, elapsed delay and setting group.

Recorded values of the under-reactance stages X<, X<< (40)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		Zn	Fault impedance
Angle		°	Fault angle
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.23. Reverse power and under-power protection P< (32)

Reverse power function can be used for generators against motoring to protect the prime mover against over-speeding or to disconnect a motor in case the supply voltage is lost and thus prevent any power generation by the motor. Under-power function can be used to detect loss of the mechanical load of a motor. Reverse and under power function is sensitive to active power. Whenever the active power goes under the pick-up value, the stage picks up and issues a start signal. If the fault situation stays on longer than the delay setting, a trip signal is issued.

Scaling of pick-up setting

The pick-up setting is proportional to the nominal power of the prime mover parameter P_m, which is part of the basic configuration.

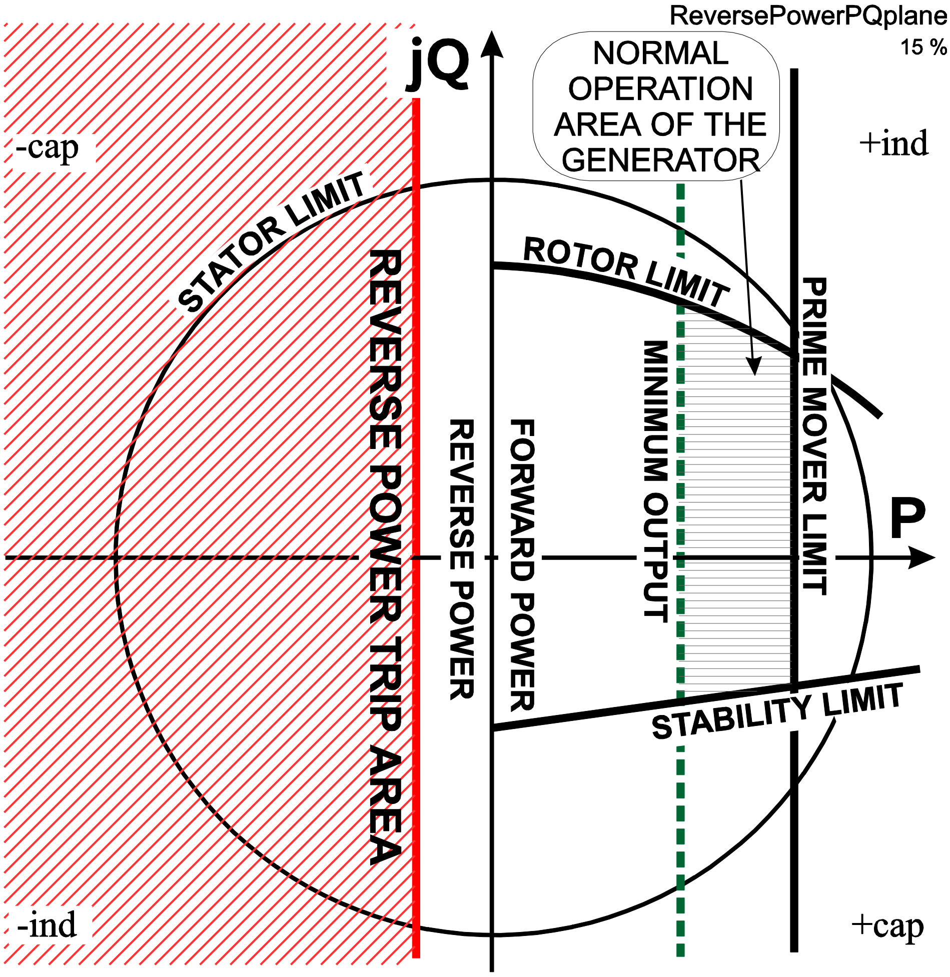


Figure 5.23-1 Characteristics of reverse power function.

Reverse power

For reverse power protection a negative pick-up value is used (Figure 5.23-1).

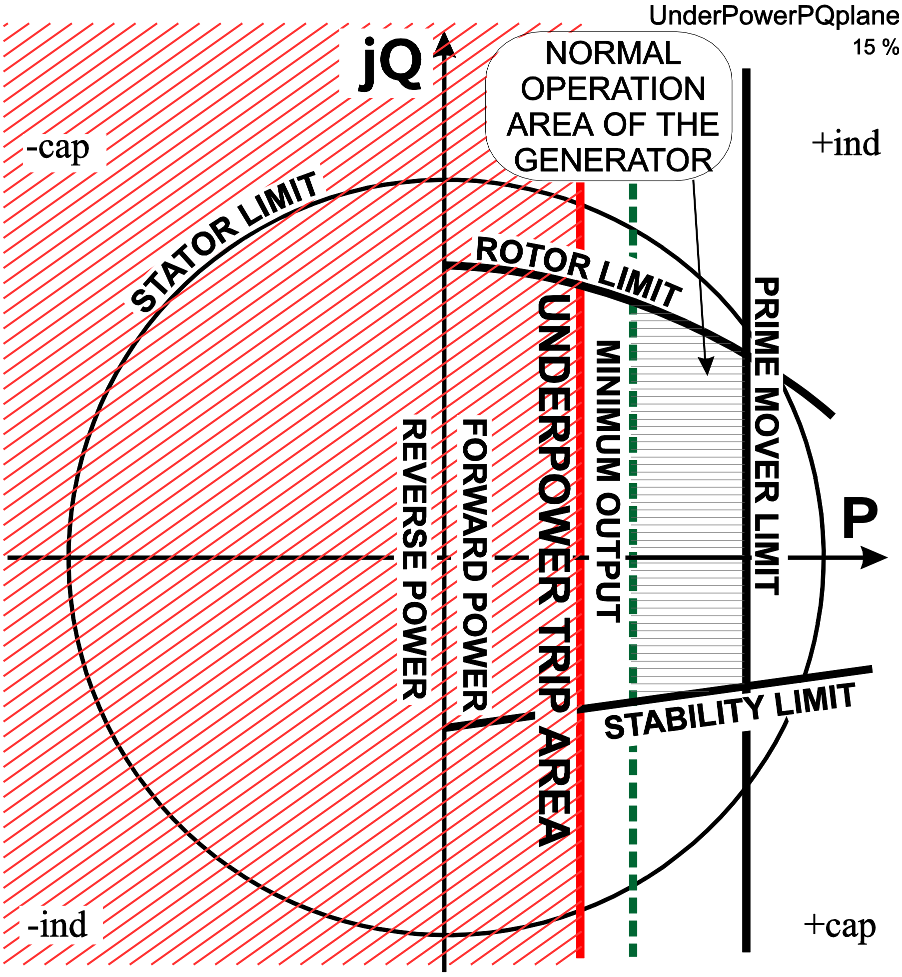


Figure 5.23-2 Characteristics of under power function.

Under power

When the pick-up value is positive, the function is called under-power (Figure 5.23-2).

Two independent stages

There are two separately adjustable stages available: P< and P<<.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

There are two identical stages available with independent setting parameters.

Parameters of the reverse/under power stages P<, P<< (32)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
P		kW	The supervised value.	
P<, P<<		kW	Pick-up value scaled to primary value.	
P<, P<<		%Pm	Pick-up value scaled to pu.	Set
t<, t<<		s	Definite operation time	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault power, elapsed delay and setting group.

Recorded values of the reverse/under power stages (8 latest faults) P<, P<< (32)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		xPm	Minimum power
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.24. Second harmonic O/C stage I_{f2}>(51F2)

This stage is mainly used to block other stages. The ratio between the second harmonic component and the fundamental frequency component is measured on all the phase currents. When the ratio in any phase exceeds the setting value, the stage gives a start signal. After a settable delay, the stage gives a trip signal.

The start and trip signals can be used for blocking the other stages.

The trip delay is irrelevant if only the start signal is used for blocking.

The trip delay of the stages to be blocked must be more than 60 ms to ensure a proper blocking.

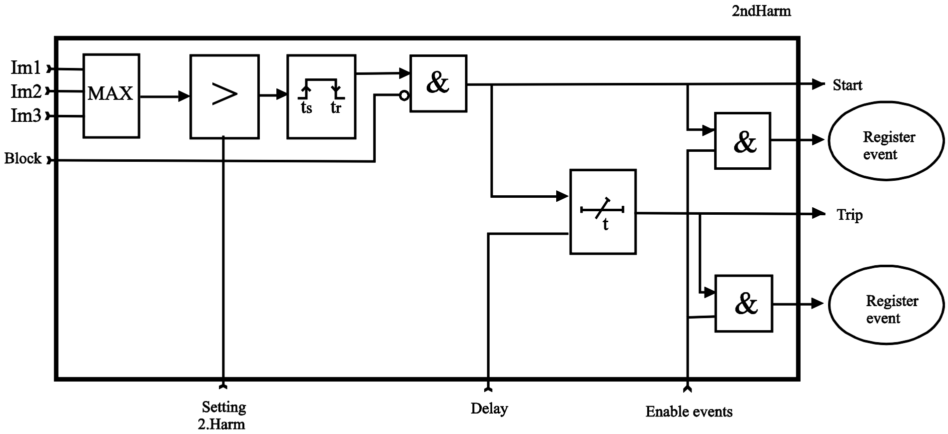


Figure 5.24-1 Block diagram of the second harmonic stage.

Setting parameters of second harmonic blocking 2.Ha(51F2):

Parameter	Value	Unit	Default	Description
If2>	10…100	%	10	Setting value If2/Ifund
t_f2	0.05…300.0	s	0.05	Definite operating time
S_On	Enabled; Disabled	-	Enabled	Start on event
S_Off	Enabled; Disabled	-	Enabled	Start off event
T_On	Enabled; Disabled	-	Enabled	Trip on event
T_Off	Enabled; Disabled	-	Enabled	Trip off event

Measured and recorded values of second harmonic blocking 2.Ha(51F2):

	Parameter	Value	Unit	Description
Measured values	IL1H2.		%	2. harmonic of IL1, proportional to the fundamental value of IL1
	IL2H2.		%	2. harmonic of IL2
	IL3H2.		%	2. harmonic of IL3
Recorded values	Flt		%	The max. fault value
	EDly		%	Elapsed time as compared to the set operating time; 100% = tripping

5.25. Fifth harmonic O/C stage I_{f5}>(51F5)

Overexiting for example a transformer creates odd harmonics. This 5th harmonic overcurrent stage can be used detect overexcitation. This stage can also be used to block some other stages.

The ratio between the fifth harmonic component and the fundamental frequency component is measured on all the phase currents. When the ratio in any phase exceeds the setting value, the stage gives a start signal. After a settable delay, the stage gives a trip signal.

The trip delay of the stages to be blocked must be more than 60 ms to ensure a proper blocking.

Setting parameters of second harmonic blocking 5.Ha(51F5):

Parameter	Value	Unit	Default	Description
If5>	10…100	%	10	Setting value If2/Ifund
t_f5	0.05…300.0	s	0.05	Definite operating time
S_On	Enabled; Disabled	-	Enabled	Start on event
S_Off	Enabled; Disabled	-	Enabled	Start off event
T_On	Enabled; Disabled	-	Enabled	Trip on event
T_Off	Enabled; Disabled	-	Enabled	Trip off event

Measured and recorded values of fifth harmonic blocking 5.Ha(51F5):

	Parameter	Value	Unit	Description
Measured values	IL1H5.		%	5. harmonic of IL1, proportional to the fundamental value of IL1
	IL2H5.		%	5. harmonic of IL2
	IL3H5.		%	5. harmonic of IL3
Recorded values	Flt		%	The max. fault value
	EDly		%	Elapsed time as compared to the set operating time; 100% = tripping

5.26. Circuit-breaker failure protection CBFP (50BF)

The circuit breaker failure protection can be used to trip any upstream circuit breaker (CB), if the fault has not disappeared within a given time after the initial trip command. A different output contact of the relay must be used for this backup trip.

The operation of the circuit-breaker failure protection (CBFP) is based on the supervision of the signal to the selected trip relay and the time the fault remains on after the trip command.

If this time is longer than the operating time of the CBFP stage, the CBFP stage activates another output relay, which will remain activated until the primary trip relay resets.

The CBFP stage is supervising all the protection stages using the same selected trip relay, since it supervises the control signal of this relay. See chapter 8.4 for details about the output matrix and the trip relays.

Parameters of the circuit breaker failure stage CBFP (50BF)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
CBrelay	1 – 2		The supervised output relay*). Relay T1 – T2 (depending the ordering code)	Set
t>		s	Definite operation time.	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

*) This setting is used by the circuit breaker condition monitoring, too. See chapter 6.8.

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp and elapsed delay.

Recorded values of the circuit breaker failure stage (8 latest faults) CBFP (50BF)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
EDly		%	Elapsed time of the operating time setting. 100% = trip

5.27. Programmable stages (99)

For special applications the user can built his own protection stages by selecting the supervised signal and the comparison mode.

The following parameters are available:

- Priority

  If operation times less than 60 milliseconds are needed select 10 ms. For operation times under one second 20 ms is recommended. For longer operation times and THD signals 100 ms is recommended.

- Link

  The name of the supervised signal (see table below).

- Cmp

  Compare mode. ‘>’ for over or ‘<’ for under comparison.

- Pick-up

  Limit of the stage. The available setting range and the unit depend on the selected signal.

- t

  Definite time operation delay

- Hyster

  Dead band (hysteresis)

- NoCmp

  Only used with compare mode under (‘<’). This is the limit to start the comparison. Signal values under NoCmp are not regarded as fault.

Available signals to be supervised by the programmable stages

IL1, IL2, IL3	Phase currents
Io1	Residual current input I_{01}
Io2	Residual current input I_{02}
U12, U23, U31	Line-to-line voltages
UL1, UL2, UL3	Phase-to-ground voltages
Uo	Zero-sequence voltage
f	Frequency
P	Active power
Q	Reactive power
S	Apparent power
IoCalc	Phasor sum $\underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3}$
I1	Positive sequence current
I2	Negative sequence current
I2/I1	Relative negative sequence current
I2/In	Negative sequence current in pu
U1	Positive sequence voltage
U2	Negative sequence voltage
U2/U1	Relative negative sequence voltage
IL	Average $(I_{L1} + I_{L2} + I_{L3)}/3$
Uphase (U_{LN})	Average $(U_{L1} + U_{L2} + U_{L3)}/3$
Uline (U_{LL})	Average $(U_{12} + U_{23} + U_{31)}/3$
TanFii	Tangent φ [=tan(arccosφ)]
Prms	Active power rms value
Qrms	Reactive power rms value
Srms	Apparnet power rms value
THDIL1	Total harmonic distortion of I_{L1}
THDIL2	Total harmonic distortion of I_{L2}
THDIL3	Total harmonic distortion of I_{L3}
THDUa	Total harmonic distortion of input U_a
THDUc	Total harmonic distortion of input U_b
THDUb	Total harmonic distortion of input U_c
IL1RMS	IL1 RMS for average sampling
IL2RMS	IL2 RMS for average sampling
IL3RMS	IL3 RMS for average sampling

Eight independent stages

The relay has eight independent programmable stages. Each programmable stage can be enabled or disabled to fit the intended application.

Setting groups

There are two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

There are two identical stages available with independent setting parameters.

Parameters of the programmable stages PrgN (99)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Link	(See table above)		Name for the supervised signal	Set
(See table above)			Value of the supervised signal	
Cmp	 > <		Mode of comparison Over protection Under protection	Set
Pickup			Pick up value scaled to primary level	
Pickup		pu	Pick up setting in pu	Set
t		s	Definite operation time.	Set
Hyster		%	Dead band setting	Set
NoCmp		pu	Minimum value to start under comparison. (Mode='<')	Set

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault value and elapsed delay.

Recorded values of the programmable stages PrgN (99)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		pu	Fault value
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

5.28. Arc fault protection (50ARC/50NARC) (optional)

NOTE! This protection function needs optional hardware in slot X6. More details of the hardware can be found in chapters 11.5 and 12.1.6).

Arc protection is used for fast arc protection. The function is based on simultaneous light and current measurement. Special arc sensors are used to measure the light of an arc.

Three stages for arc faults

There are three separate stages for the various current inputs:

- ArcI> for phase-to-phase arc faults. Current inputs IL1, IL2, IL3 are used.
- ArcI_{01}> for phase-to-earth arc faults. Current input I_{01} is used.
- ArcI_{02}> for phase-to-earth arc faults. Current input I_{02} is used.

Light channel selection

The light information source to the stages can be selected from the following list.

- – No sensor selected. The stage will not work.
- S1 Light sensor S1.
- S2 Light sensor S2.
- S1/S2 Either one of the light sensors S1 or S2.
- BI Binary input of the arc card. 48 Vdc.
- S1/BI Light sensor S1 or the binary input.
- S2/BI Light sensor S2 or the binary input.
- S1/S2/BI Light sensor S1 or S2 or the binary input.

Binary input

The binary input (BI) on the arc option card (see chapter 11.5) can be used to get the light indication from another relay to build selective arc protection systems. The BI signal can also be connected to any of the output relays, BO, indicators etc. offered by the output matrix (See chapter 8.4). BI is a dry input for 48 Vdc signal from binary outputs of other VAMP relays or dedicated arc protection devices by VAMP.

Binary output

The binary output (BO) on the arc option card (see chapters 11.5 and 11.6) can be used to give the light indication signal or any other signal or signals to another relay's binary input to build selective arc protection systems. Selection of the BO connected signal(s) is done with the output matrix (See chapter 8.4). BO is an internally wetted 48 Vdc signal for BI of other VAMP relays or dedicated arc protection devices by VAMP.

Delayed light indication signal

Relay output matrix has a delayed light indication output signal (Delayed Arc L>) available for building selective arc protection systems. Any light source combination and a delay can be configured starting from 0.01 s to 0.15 s. The resulting signal is available in the output matrix to be connected to BO, output relays etc.

Pick up scaling

The per unit (pu) values for pick up setting are based on the current transformer values.

ArcI>:	1 pu = 1xI_N = rated phase current CT value
ArcI_{01}>:	1 pu = 1xI_{01N} = rated residual current CT value for input I_{01}.
ArcI_{02}>:	1 pu = 1xI_{02N} = rated residual current CT value for input I_{02}.

Parameters of arc protection stages ArcI>, ArcI$_{01}$A, ArcI$_{02}$> (50ARC/50NARC)

Parameter	Value	Unit	Description	Note
Status	- Start Trip		Current status of the stage Light detected according ArcIn Light and overcurrent detected	 F F
LCntr			Cumulative light indication counter. S1, S2 or BI.	C
SCntr			Cumulative light indication counter for the selected inputs according parameter ArcIn	C
TCntr			Cumulative trip counter	C
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
 ILmax Io1 Io2			Value of the supervised signal Stage ArcI> Stage ArcI$_{01}$> Stage ArcI$_{02}$>	
ArcI> ArcIo1> ArcIo2>		pu pu pu	Pick up setting xI$_N$ Pick up setting xI$_{01N}$ Pick up setting xI$_{02N}$	Set
ArcIn	 – S1 S2 S1/S2 BI S1/BI S2/BI S1/S2/BI		Light indication source selection No sensor selected Sensor 1 at terminals X6:4-5 Sensor 2 at terminals X6:6-7 Terminals X6:1-3	Set
Delayed light signal output				
Ldly		s	Delay for delayed light output signal	Set
LdlyCn	 – S1 S2 S1/S2 BI S1/BI S2/BI S1/S2/BI		Light indication source selection No sensor selected Sensor 1 at terminals X6:4-5 Sensor 2 at terminals X6:6-7 Terminals X6:1-3	Set

For details of setting ranges see chapter 12.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault type, fault value, load current before the fault and elapsed delay.

Recorded values of the arc protection stages ArcI>, ArcI$_{01}$A, ArcI$_{02}$> (50ARC/50NARC)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Type		pu	Fault type value. Only for ArcI> stage.
Flt		pu	Fault value
Load		pu	Pre fault current. Only for ArcI> stage.
EDly		%	Elapsed time of the operating time setting. 100% = trip

5.29. Inverse time operation

The inverse time operation - i.e. inverse delay minimum time (IDMT) type of operation - is available for several protection functions. The common principle, formulae and graphic representations of the available inverse delay types are described in this chapter.

Inverse delay means that the operation time depends on the measured real time process values during a fault. For example with an overcurrent stage using inverse delay a bigger a fault current gives faster operation. The alternative to inverse delay is definite delay. With definite delay a preset time is used and the operation time does not depend on the size of a fault..

Stage specific inverse delay

Some protection functions have their own specific type of inverse delay. Details of these dedicated inverse delays are described with the appropriate protection function.

Operation modes

There are three operation modes to use the inverse time characteristics:

1. **Standard delays**
   Using standard delay characteristics by selecting a curve family (IEC, IEEE, IEEE2, RI) and a delay type (Normal inverse, Very inverse etc). See chapter 5.29.1.
2. **Standard delay formulae with free parameters**
   Selecting a curve family (IEC, IEEE, IEEE2) and defining one's own parameters for the selected delay formula. This mode is activated by setting delay type to 'Parameters', and then editing the delay function parameters A ... E. See chapter 5.29.2.
3. **Fully programmable inverse delay characteristics**
   Building the characteristics by setting 16 [current, time] points. The relay interpolates the values between given points with 2nd degree polynomials. This mode is activated by setting curve family to 'PrgN''. There are maximum three different programmable curves available at the same time. Each programmed curve can be used by any number of protection stages. See chapter 5.29.3.

Local panel graph

The relay will show a graph of the currently used inverse delay on the local panel display. Up and down keys can be used for zooming. Also the delays at $20xI_{SET}$, $4xI_{SET}$ and $2xI_{SET}$ are shown.

Inverse time setting error signal

If there are any errors in the inverse delay configuration the appropriate protection stage will use definite time delay.

There is a signal ‘Setting Error’ available in output matrix, which indicates three different situations:

1. Settings are currently changed with VAMPSET or local panel, and there is temporarily an illegal combination of curve/delay/points. For example if previous settings were IEC/NI and then curve family is changed to IEEE, the setting error will active, because there is no NI type available for IEEE curves. After changing valid delay type for IEEE mode (for example MI), the ‘Setting Error’ signal will release.
2. There are errors in formula parameters A…E, and the device is not able to build the delay curve
3. There are errors in the programmable curve configuration and the device is not able to interpolate values between the given points.

Limitation

The maximum measured phase current is $50xI_N$ and the maximum directly measured earth fault current is $5xI_{0N}$. This limits the scope of inverse curves when the setting is more than $2.5xI_N$ (overcurrent stages and earth fault stages using I_{0Calc} input) or $0.25xI_{01N}$ (earth fault stages using I_{01} input or I_{02} input). The I_N and I_{01N} and I_{02N} depend on the order code (See chapter 15). The table below gives the limit values in secondary amperes.

Example of limitation

CT = 750/5

I_{GN} = 577 A

CT_0 = 100/1 (a cable CT for I_0)

Secondary scaled I_{GNsec} is now 3.85 A

For 5 A CT secondaries and 1 A residual current inputs VAMP relay VAMP 210-5D7AAA is used. It has 5 A phase current inputs and 1 A residual inputs.

For overcurrent stage I> the table below gives 12.5 A. Thus the maximum setting for I> stage giving full inverse delay range is 12.5 A / 3.85 A = 3.25 xI_{GN}.

For earth fault stage I_0> and input I_{01} the table below gives 0.25 A. Thus the maximum setting for I_0> stage giving full inverse delay range is 0.25 A / 1 A = 0.25 pu. This equals a 25 A primary earth fault current.

When using input signal I_{0Calc} the corresponding setting is 12.5 A / 1 A = 12.5 pu. This equals a 9375 A of primary earth fault current.

	RATED INPUT			Maximum secondary scaled setting enabling inverse delay times up to 20x setting		
Order code	I_L	I_{01}	I_{02}	I_{L1}, I_{L2}, I_{L3} & I_{0Calc}	I_{01}	I_{02}
VAMP 210-1_	1			2.5 A		
VAMP 210-5_	5			12.5 A		
VAMP 210-_A		5	5		1.25 A	1.25 A
VAMP 210-_B		5	1		1.25 A	0.25 A
VAMP 210-_C		1	5		0.25 A	1.25 A
VAMP 210-_D		1	1		0.25 A	0.25 A

5.29.1. Standard inverse delays IEC, IEEE, IEEE2, RI

The available standard inverse delays are divided in four categories IEC, IEEE, IEEE2 and RI called delay curve families. Each category of family contains a set of different delay types according the following table.

Inverse time setting error signal

The inverse time setting error signal will be activated, if the delay category is changed and the old delay type doesn't exist in the new category. See chapter 5.29 for more details.

Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. See chapter 5.29 for more details.

Table 5.29.1-1. Available standard delay families and the available delay types within each family.

Delay type		Curve family				
		DT	**IEC**	**IEEE**	**IEEE2**	**RI**
DT	Definite time	X				
NI1	Normal inverse		X		X	
VI	Very inverse		X	X	X	
EI	Extremely inverse		X	X	X	
LTI	Long time inverse		X	X		
LTEI	Long time extremely inverse			X		
LTVI	Long time very inverse			X		
MI	Moderately inverse			X	X	
STI	Short time inverse			X		
STEI	Short time extremely inverse			X		
RI	Old ASEA type					X
RXIDG	Old ASEA type					X

IEC inverse time operation

The operation time depends on the measured value and other parameters according Equation 5.29.1-1 . Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.29.1-1

$$t = \frac{k\ A}{\left(\frac{I}{I_{pickup}}\right)^B - 1}$$

t	=	Operation delay in seconds
k	=	User's multiplier
I	=	Measured value
Ipickup	=	User's pick up setting
A, B	=	Constants parameters according Table 5.29.1-2.

There are three different delay types according IEC 60255-3, Normal inverse (NI), Extremely inverse (EI), Very inverse (VI) and a VI extension. Additional there is a de facto standard Long time inverse (LTI).

Table 5.29.1-2 Constants for IEC inverse delay equation

Delay type		Parameter	
		A	B
NI	Normal inverse	0.14	0.02
EI	Extremely inverse	80	2
VI	Very inverse	13.5	1
LTI	Long time inverse	120	1

Example for Delay type "Normal inverse (NI) ":

k	=	0.50
I	=	4 pu (constant current)
I_{pickup}	=	2 pu
A	=	0.14
B	=	0.02

$$t = \frac{0.50 \cdot 0.14}{\left(\frac{4}{2}\right)^{0.02} - 1} = 5.0$$

The operation time in this example will be 5 seconds. The same result can be read from Figure 5.29.1-1.

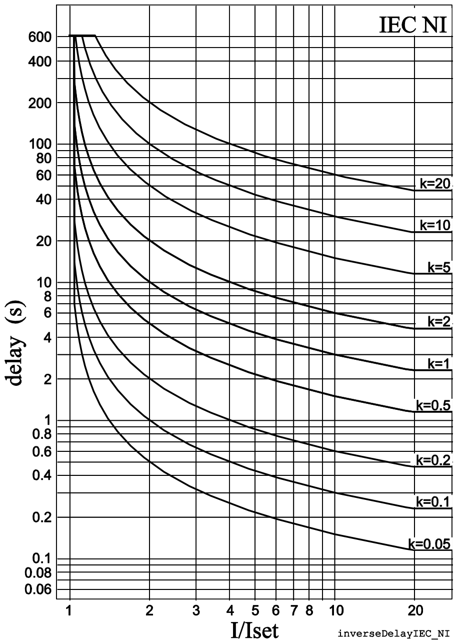


Figure 5.29.1-1 IEC normal inverse delay.

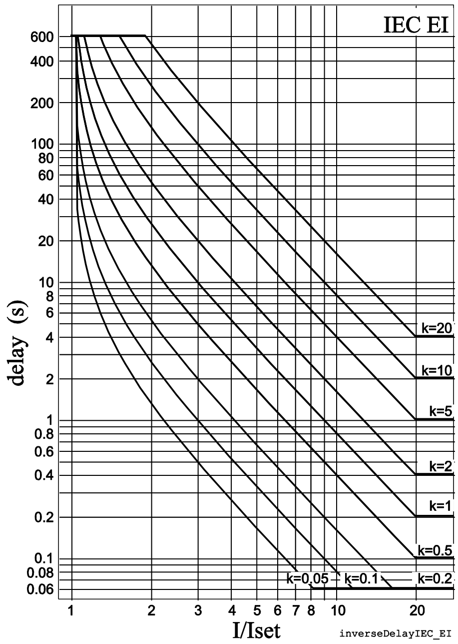


Figure 5.29.1-2 IEC extremely inverse delay.

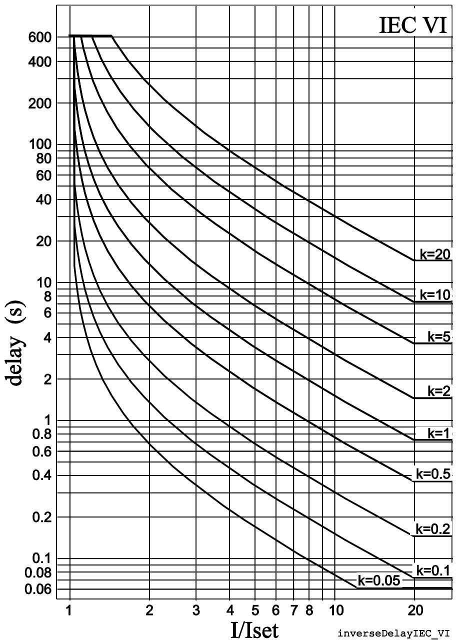


Figure 5.29.1-3 IEC very inverse delay.

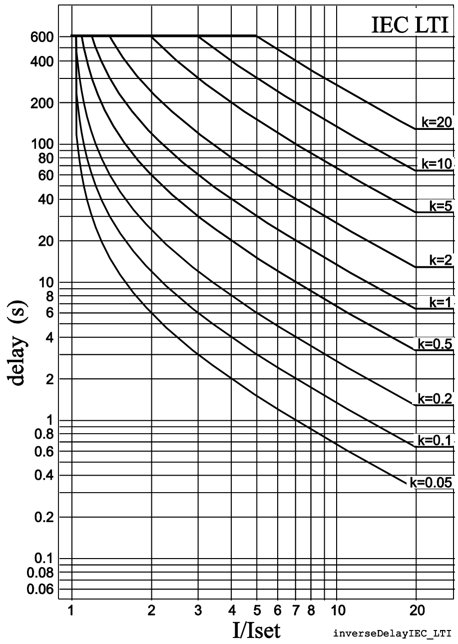


Figure 5.29.1-4 IEC long time inverse delay.

IEEE/ANSI inverse time operation

There are three different delay types according IEEE Std C37.112-1996 (MI, VI, EI) and many de facto versions according Table 5.29.1-3. The IEEE standard defines inverse delay for both trip and release operations. However, in the device only the trip time is inverse according the standard but the release time is constant.

The operation delay depends on the measured value and other parameters according Equation 5.29.1-2. Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.29.1-2

$$t = k\left[\frac{A}{\left(\frac{I}{I_{pickup}}\right)^{C} - 1} + B\right]$$

t	=	Operation delay in seconds
k	=	User's multiplier
I	=	Measured value
I_{pickup}	=	User's pick up setting
A,B,C	=	Constant parameter according Table 5.29.1-3.

Table 5.29.1-3 Constants for IEEE/ANSI inverse delay equation

Delay type		Parameter		
		A	B	C
LTI	Long time inverse	0.086	0.185	0.02
LTVI	Long time very inverse	28.55	0.712	2
LTEI	Long time extremely inverse	64.07	0.250	2
MI	Moderately inverse	0.0515	0.1140	0.02
VI	Very inverse	19.61	0.491	2
EI	Extremely inverse	28.2	0.1217	2
STI	Short time inverse	0.16758	0.11858	0.02
STEI	Short time extremely inverse	1.281	0.005	2

Example for Delay type "Moderately inverse (MI)":

k	=	0.50
I	=	4 pu
I_{pickup}	=	2 pu
A	=	0.0515
B	=	0.114
C	=	0.02

$$t = 0.50 \cdot \left[\frac{0.0515}{\left(\frac{4}{2}\right)^{0.02} - 1} + 0.1140 \right] = 1.9$$

The operation time in this example will be 1.9 seconds. The same result can be read from Figure 5.29.1-8.

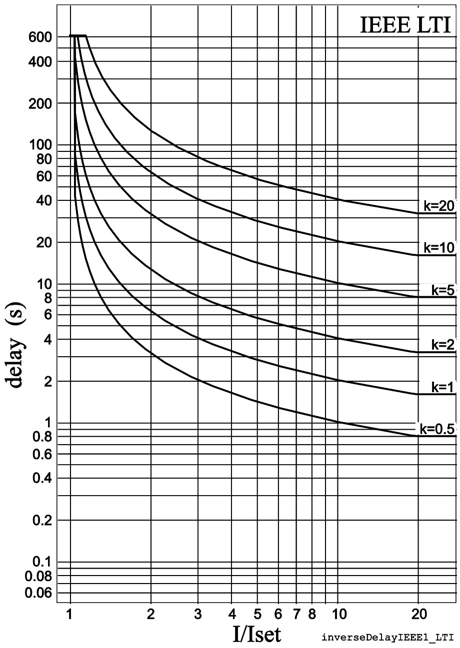


Figure 5.29.1-5 ANSI/IEEE long time inverse delay

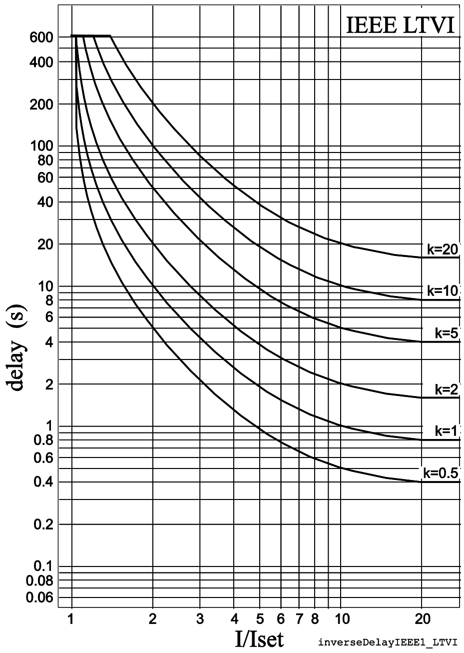


Figure 5.29.1-6 ANSI/IEEE long time very inverse delay

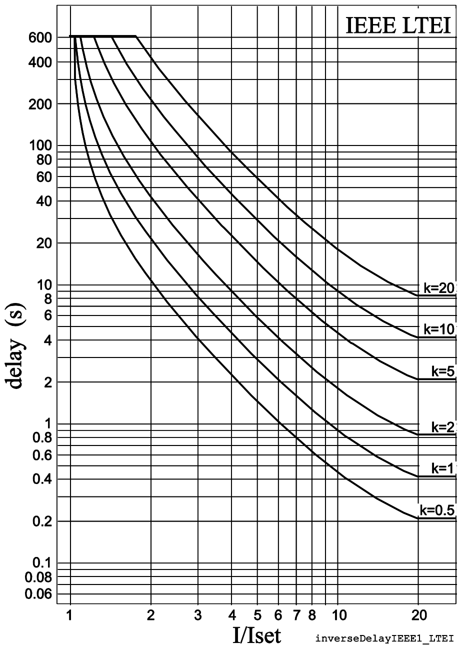


Figure 5.29.1-7 ANSI/IEEE long time extremely inverse delay

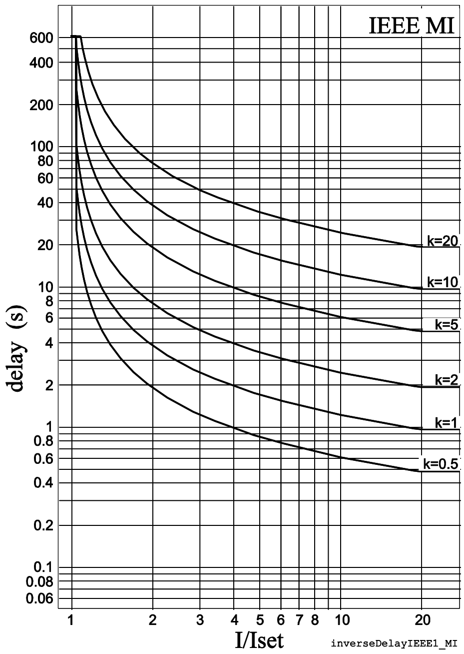


Figure 5.29.1-8 ANSI/IEEE moderately inverse delay

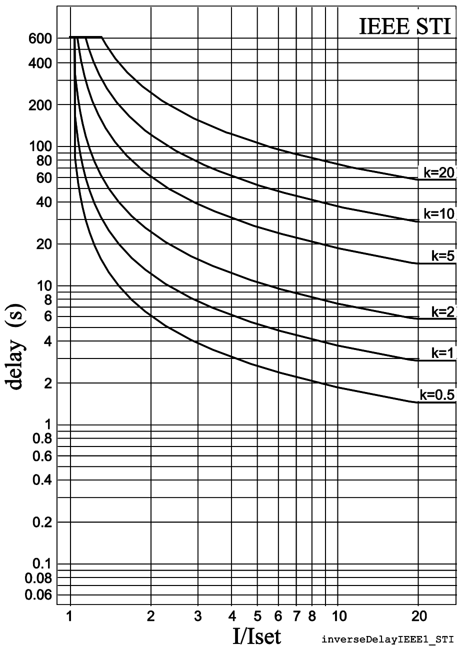


Figure 5.29.1-9 ANSI/IEEE short time inverse delay

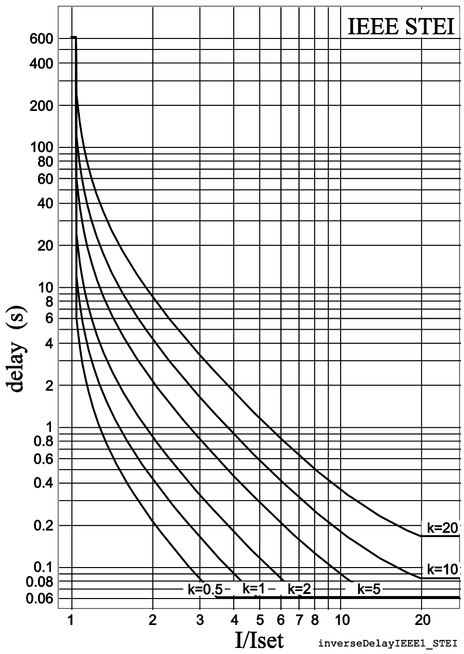


Figure 5.29.1-10 ANSI/IEEE short time extremely inverse delay

IEEE2 inverse time operation

Before the year 1996 and ANSI standard C37.112 microprocessor relays were using equations approximating the behaviour of various induction disc type relays. A quite popular approximation is Equation 5.29.1-3, which in the device is called IEEE2. Another name could be IAC, because the old General Electric IAC relays have been modeled using the same equation.

There are four different delay types according Table 5.29.1-4. The old electromechanical induction disc relays have inverse delay for both trip and release operations. However, in the device only the trip time is inverse the release time being constant.

The operation delay depends on the measured value and other parameters according Equation 5.29.1-3. Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.29.1-3

$$t = k\left[A + \frac{B}{\left(\frac{I}{I_{pickup}} - C\right)} + \frac{D}{\left(\frac{I}{I_{pickup}} - C\right)^2} + \frac{E}{\left(\frac{I}{I_{pickup}} - C\right)^3}\right]$$

t	=	Operation delay in seconds
k	=	User's multiplier
I	=	Measured value
I_{pickup}	=	User's pick up setting
A,B,C,D	=	Constant parameter according Table 5.29.1-4.

Table 5.29.1-4 Constants for IEEE2 inverse delay equation

Delay type		Parameter				
		A	B	C	D	E
MI	Moderately inverse	0.1735	0.6791	0.8	-0.08	0.1271
NI	Normally inverse	0.0274	2.2614	0.3	-.1899	9.1272
VI	Very inverse	0.0615	0.7989	0.34	-0.284	4.0505
EI	Extremely inverse	0.0399	0.2294	0.5	3.0094	0.7222

Example for Delay type "Moderately inverse (MI)":

k	=	0.50
I	=	4 pu
I_{pickup}	=	2 pu
A	=	0.1735
B	=	0.6791
C	=	0.8
D	=	-0.08
E	=	0.127

$$t = 0.5 \cdot \left[0.1735 + \frac{0.6791}{\left(\frac{4}{2} - 0.8\right)} + \frac{-0.08}{\left(\frac{4}{2} - 0.8\right)^2} + \frac{0.127}{\left(\frac{4}{2} - 0.8\right)^3} \right] = 0.38$$

The operation time in this example will be 0.38 seconds. The same result can be read from Figure 5.29.1-11.

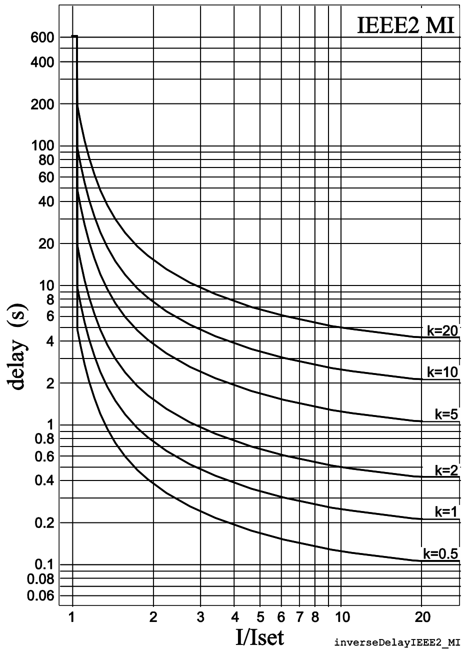


Figure 5.29.1-11 IEEE2 moderately inverse delay

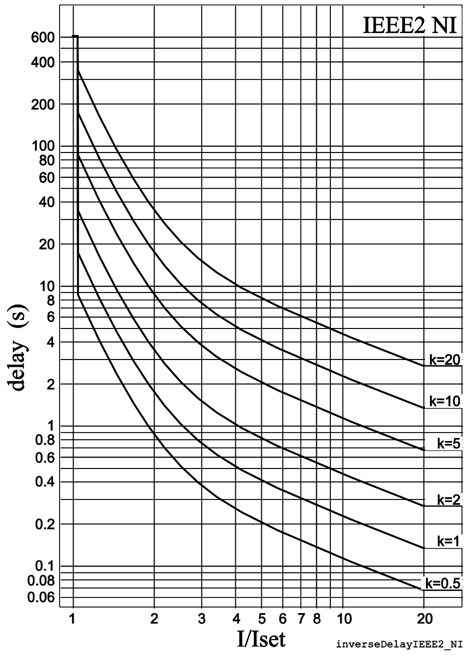


Figure 5.29.1-12 IEEE2 normal inverse delay

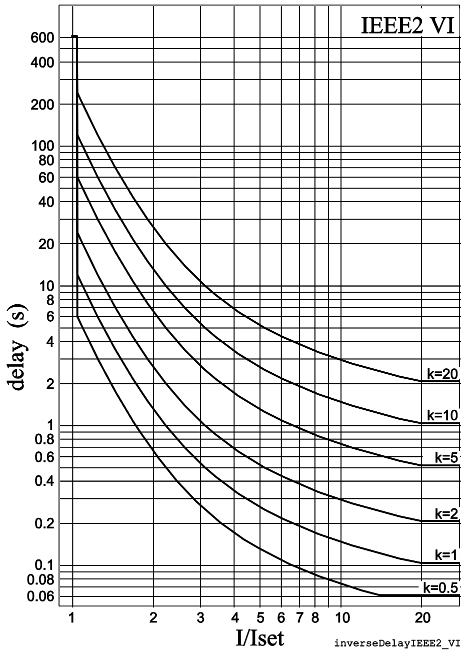


Figure 5.29.1-13 IEEE2 very inverse delay

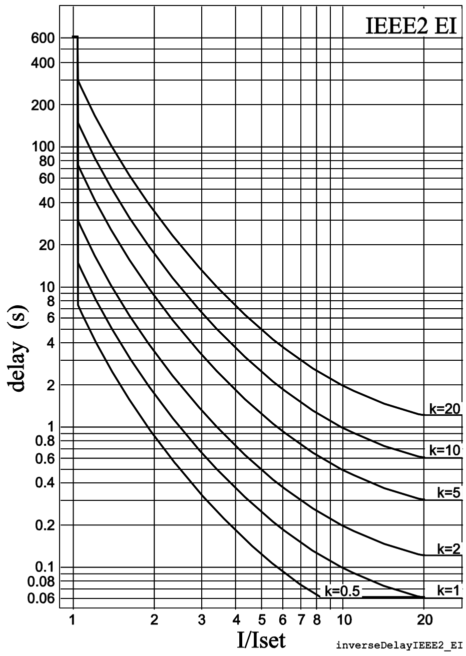


Figure 5.29.1-14 IEEE2 extremely inverse delay

RI and RXIDG type inverse time operation

These two inverse delay types have their origin in old ASEA (nowadays ABB) earth fault relays.

The operation delay of types RI and RXIDG depends on the measured value and other parameters according Equation 5.29.1-4 and Equation 5.29.1-5. Actually these equations can only be used to draw graphs or when the measured value I is constant during the fault. Modified versions are implemented in the relay for real time usage.

Equation 5.29.1-4. RI

$$t_{RI} = \frac{k}{0.339 - \dfrac{0.236}{\left(\dfrac{I}{I_{pickup}}\right)}}$$

Equation 5.29.1-5 RXIDG

$$t_{RXIDG} = 5.8 - 1.35 \ln \frac{I}{k\, I_{pickup}}$$

t	=	Operation delay in seconds
k	=	User's multiplier
I	=	Measured value
I_{pickup}	=	User's pick up setting

Example for Delay type RI :

k = 0.50

I = 4 pu

I_{pickup} = 2 pu

$$t_{RI} = \frac{0.5}{0.339 - \frac{0.236}{\left(\frac{4}{2}\right)}} = 2.3$$

The operation time in this example will be 2.3 seconds. The same result can be read from Figure 5.29.1-15.

Example for Delay type RXIDG:

k = 0.50

I = 4 pu

I_{pickup} = 2 pu

$$t_{RXIDG} = 5.8 - 1.35 \ln \frac{4}{0.5 \cdot 2} = 3.9$$

The operation time in this example will be 3.9 seconds. The same result can be read from Figure 5.29.1-16.

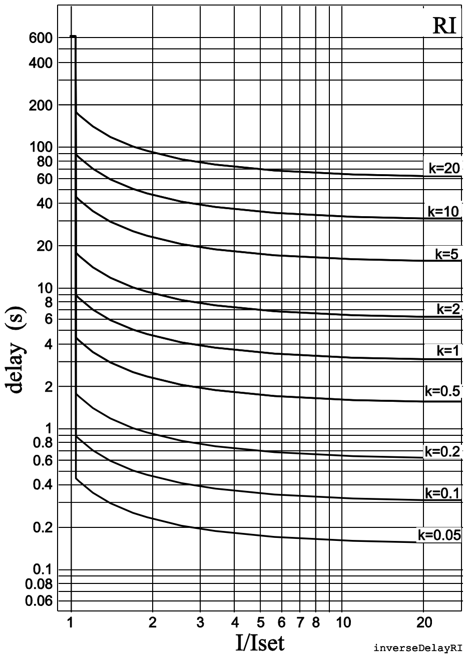


Figure 5.29.1-15 Inverse delay of type RI.

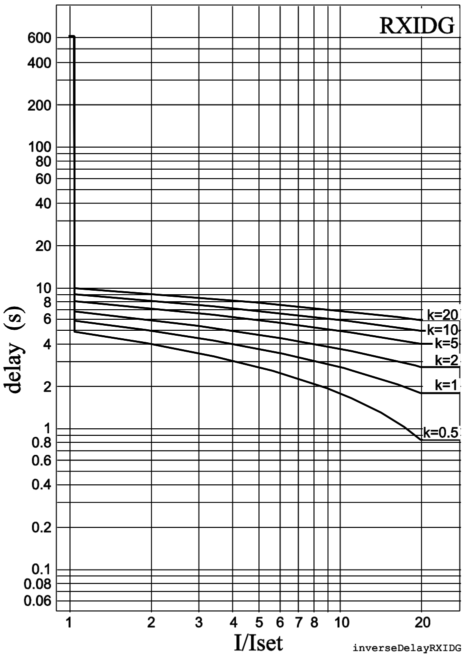


Figure 5.29.1-16 Inverse delay of type RXIDG.

5.29.2. Free parametrisation using IEC, IEEE and IEEE2 equations

This mode is activated by setting delay type to ‘Parameters’, and then editing the delay function constants, i.e. the parameters A ... E. The idea is to use the standard equations with one’s own constants instead of the standardized constants as in the previous chapter.

Example for GE-IAC51 delay type inverse:

k	=	0.50
I	=	4 pu
I_{pickup}	=	2 pu
A	=	0.2078
B	=	0.8630
C	=	0.8000
D	=	–0.4180
E	=	0.1947

$$t = 0.5 \cdot \left[0.2078 + \frac{0.8630}{\left(\frac{4}{2} - 0.8\right)} + \frac{-0.4180}{\left(\frac{4}{2} - 0.8\right)^2} + \frac{0.1947}{\left(\frac{4}{2} - 0.8\right)^3} \right] = 0.37$$

The operation time in this example will be 0.37 seconds.

The resulting time/current characteristic of this example matches quite well with the characteristic of the old electromechanical IAC51 induction disc relay.

Inverse time setting error signal

The inverse time setting error signal will become active, if interpolation with the given parameters is not possible. See chapter 5.29 for more details.

Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. See chapter 5.29 for more details.

5.29.3. Programmable inverse time curves

Only with VAMPSET, requires rebooting.

The [current, time] curve points are programmed using VAMPSET PC program. There are some rules for defining the curve points:

- configuration must begin from the topmost row
- row order must be as follows: the smallest current (longest operation time) on the top and the largest current (shortest operation time) on the bottom
- all unused rows (on the bottom) should be filled with [1.00 0.00s]

Here is an example configuration of curve points:

Point	Current $I/I_{pick-up}$	Operation delay
1	1.00	10.00 s
2	2.00	6.50 s
3	5.00	4.00 s
4	10.00	3.00 s
5	20.00	2.00 s
6	40.00	1.00 s
7	1.00	0.00 s
8	1.00	0.00 s
9	1.00	0.00 s
10	1.00	0.00 s
11	1.00	0.00 s
12	1.00	0.00 s
13	1.00	0.00 s
14	1.00	0.00 s
15	1.00	0.00 s
16	1.00	0.00 s

Inverse time setting error signal

The inverse time setting error signal will be activated, if interpolation with the given points fails. See chapter 5.29 for more details.

Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. See chapter 5.29 for more details.

6. Supporting functions

6.1. Event log

Event log is a buffer of event codes and time stamps including date and time. For example each start-on, start-off, trip-on or trip-off of any protection stage has a unique event number code. Such a code and the corresponding time stamp is called an event. The event codes are listed in a separate document Modbus_Profibus_Spabus_event.pdf.

As an example of information included with a typical event an overvoltage trip event of the first 59 stage U> is shown in the following table.

EVENT	Description	Local panel	Communication protocols
Code: 30E2	Channel 30, event 2	Yes	Yes
U> trip on	Event text	Yes	No
112.0 %Ugn	Fault value	Yes	No
2007-01-31	Date	Yes	Yes
08:35:13.413	Time	Yes	Yes
Type: U12,23,31	Fault type	Yes	No

Events are the major data for a SCADA system. SCADA systems are reading events using any of the available communication protocols. Event log can also be scanned using the front panel or using VAMPSET. With VAMSET the events can be stored to a file especially in case the relay is not connected to any SCADA system.

Only the latest event can be read when using communication protocols or VAMPSET. Every reading increments the internal read pointer to the event buffer. (In case of communication error, the latest event can be reread any number of times using an other parameter.) On the local panel scanning the event buffer back and forth is possible.

Event enabling/masking

In case of an uninteresting event, it can be masked, which prevents the particular event(s) to be written in the event buffer.

As a default there is room for 200 latest events in the buffer. Event buffer size can be modified from 50 to 2000 in all v.10.xx softwares. Modification can be done in “Local panel conf” –menu. Alarm screen (popup screen) can also be enabled in this same menu when Vampset –setting tool is used. The oldest one will be overwritten, when a new event does occur. The shown resolution of a time stamp is one millisecond, but the actual resolution depends of the particular function creating the event. For example most protection stages create events with 10 ms or 20 ms resolution. The absolute accuracy of all time stamps depends on

the time synchronizing of the relay. See chapter 6.10 for system clock synchronizing.

Event buffer overflow

The normal procedure is to poll events from the device all the time. If this is not done, the event buffer will eventually overflow. On the local screen this is indicated with string "OVF" after the event code.

Setting parameters for events

Parameter	Value	Description	Note
Count		Number of events	
ClrEn	 – Clear	Clear event buffer	Set
Order	 Old-New New-Old	Order of the event buffer for local display	Set
FVSca	 PU Pri	Scaling of event fault value Per unit scaling Primary scaling	Set
Display Alarms	On Off	Alarm pop-up display is enabled No alarm display	Set
FORMAT OF EVENTS ON THE LOCAL DISPLAY			
Code: CHENN		CH = event channel, NN=event code	
Event description		Event channel and code in plain text	
yyyy-mm-dd		Date (for available date formats see chapter 6.10)	
hh:mm:ss.nnn		Time	

6.2. Disturbance recorder

The disturbance recorder can be used to record all the measured signals, that is, currents, voltages and the status information of digital inputs (DI) and digital outputs (DO). The digital inputs include also the arc protection signals S1, S2, BI and BO, if the optional arc protection is available.

Triggering the recorder

The recorder can be triggered by any start or trip signal from any protection stage or by a digital input. The triggering signal is selected in the output matrix (vertical signal DR). The recording can also be triggered manually. All recordings are time stamped.

Reading recordings

The recordings can be uploaded, viewed and analysed with the VAMPSET program. The recording is in COMTRADE format. This means that also other programs can be used to view and analyse the recordings made by the relay.

For more details, please see a separate VAMPSET manual.

Number of channels

At the maximum, there can be 12 recordings, and the maximum selection of channels in one recording is also 12 (limited in waveform recording). The digital inputs reserve one channel (includes all the inputs). Also the digital outputs reserve one channel (includes all the outputs). If digital inputs and outputs are recorded, there will be still 10 channels left for analogue waveforms.

Available channels

The following channels i.e. signals can be linked to a disturbance recorder:

Channel	Description	Available for waveform Voltage measurement mode	
		"2LL+Uo"	"3LN"
IL1, IL2, IL3	Phase current	Yes	Yes
Io1, Io2	Measured residual current	Yes	Yes
U12, U23	Line-to-line voltage	Yes	–
U31	Line-to-line voltage	–	–
UL1, UL2, UL3	Phase-to-neutral voltage	–	Yes
Uo	Zero sequence voltage	Yes	–
f	Frequency	–	–
P, Q, S	Active, reactive, apparent power	–	–
P.F.	Power factor	–	–
CosFii	$\cos\varphi$	–	–
IoCalc	Phasor sum Io = ($\underline{I}$L1+$\underline{I}$L2+$\underline{I}$L3)/3	–	–
I1	Positive sequence current	–	–
I2	Negative sequence current	–	–
I2/I1	Relative current unbalance	–	–
I2/Ign	Current unbalance [xI_{GN}]	–	–
U1	Positive sequence voltage	–	–
U2	Negative sequence voltage	–	–
U2/U1	Relative voltage unbalance	–	–
IL	Average (IL1 + IL2 + IL3)/3	–	–
Uphase	Average (UL1 + UL2 + UL3)/3	–	–
Uline	Average (U12 + U23 + U31)/3	–	–
DO	Digital outputs	Yes	Yes
DI	Digital inputs	Yes	Yes
TanFii	$\tan\varphi$	–	–
Prms	Active power rms value	–	–
Qrms	Reactive power rms value	–	–
Srms	Apparent power rms value	–	–
THDIL1	Total harmonic distortion of IL1	–	–
THDIL2	Total harmonic distortion of IL2	–	–
THDIL3	Total harmonic distortion of IL3	–	–
THDUa	Total harmonic distortion of input Ua	–	–
THDUb	Total harmonic distortion of input Ub	–	–
THDUc	Total harmonic distortion of input Uc	–	–
IL1RMS	IL1 RMS for average sampling	–	–
IL2RMS	IL2 RMS for average sampling	–	–
IL3RMS	IL3 RMS for average sampling	–	–

Disturbance recorder parameters

Parameter	Value	Unit	Description	Note
Mode	 Saturated Overflow		Behaviour in memory full situation: No more recordings are accepted The oldest recorder will be overwritten	Set
SR	 32/cycle 16/cycle 8/cycle 1/10ms 1/20ms 1/200ms 1/1s 1/5s 1/10s 1/15s 1/30s 1/1min		Sample rate Waveform Waveform Waveform One cycle value *) One cycle value **) Average Average Average Average Average Average Average	Set
Time		s	Recording length	Set
PreTrig		%	Amount of recording data before the trig moment	Set
MaxLen		s	Maximum time setting. This value depends on sample rate, number and type of the selected channels and the configured recording length.	
Status	 – Run Trig FULL		Status of recording Not active Waiting a triggering Recording Memory is full in saturated mode	
ManTrig	 – Trig		Manual triggering	Set
ReadyRec	n/m		n = Available recordings m = maximum number of recordings The value of 'm' depends on sample rate, number and type of the selected channels and the configured recording length.	

Parameter	Value	Unit	Description	Note
AddCh	IL1, IL2, IL3 Io1, Io2 U12, U23, U31 UL1, UL2, UL3 Uo f P, Q, S P.F. CosFii IoCalc I1, I2, I2/I1 I2/Ign U1, U2, U2/U1 IL Uphase, Uline DO, DI TanFii THDIL1 THDIL2 THDIL3 THDUa THDUb THDUc IL1RMS IL2RMS IL3RMS		Add one channel. Maximum simultaneous number of channels is 12.	Set
ClrCh	– Clear		Remove all channels	Set
(Ch)			List of selected channels	

For details of setting ranges see chapter 12.4.

Set = An editable parameter (password needed)

*) This is the fundamental frequency rms value of one cycle updated every 10 ms.

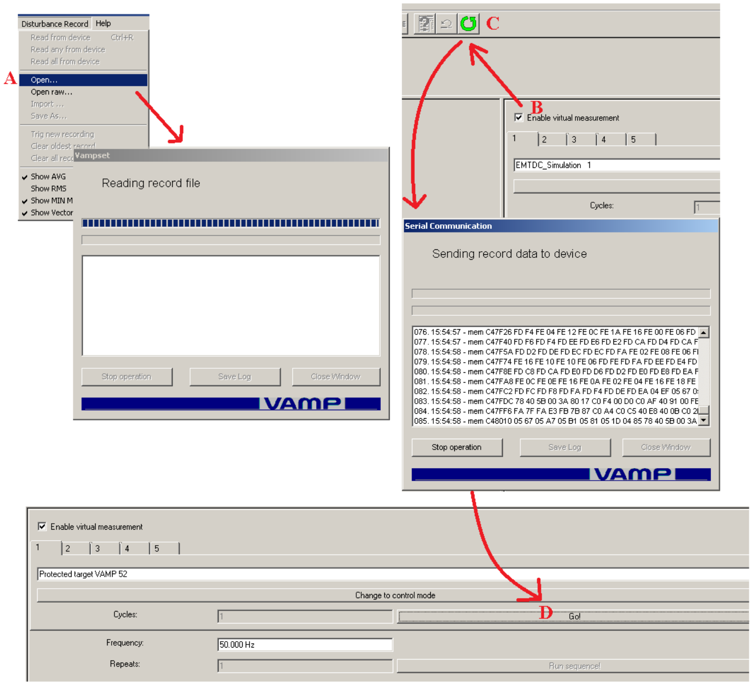
**) This is the fundamental frequency rms value of one cycle updated every 20 ms.

Running virtual comtrade files with VAMP relays

Virtual comtrade files can be run with VAMP relays with the v.10.74 software or a later version. Relay behaviour can be analysed by playing the recorder data over and over again in the relay memory.

Steps of opening the VAMPSET setting tool.

1. Go to “Disturbance record” and select Open… (A).
2. Select the comtrade file from you hard disc or equivalent. VAMPSET is now ready to read the recording.
3. The virtual measurement has to be enabled (B) in order to send record data to the relay (C).
4. Sending the file to the relay’s memory takes a few seconds. Initiate playback of the file by pressing the Go! button (D). The “Change to control mode” button takes you back to the virtual measurement.



Note! The sample rate of the comtrade file has to be 32/cycle (625 φs when 50 Hz is used). The channel names have to correspond to the channel names in Vamp relays: IL1, IL2, IL3, Io1, Io2, U12, U23, UL1, UL2, UL3 and Uo.

6.3. Cold load pick-up and inrush current detection

Cold load pick-up

A situation is regarded as cold load when all the three phase currents have been less than a given idle value and then at least one of the currents exceeds a given pick-up level within 80 ms. In such case the cold load detection signal is activated for a given time. This signal is available for output matrix and blocking matrix. Using virtual outputs of the output matrix setting group control is possible.

Application for cold load detection

Right after closing a circuit breaker a given amount of overload can be allowed for a given limited time to take care of concurrent thermostat controlled loads. Cold load pick-up function does this for example by selecting a more coarse setting group for over-current stage(s). It is also possible to use the cold load detection signal to block any set of protection stages for a given time.

Inrush current detection

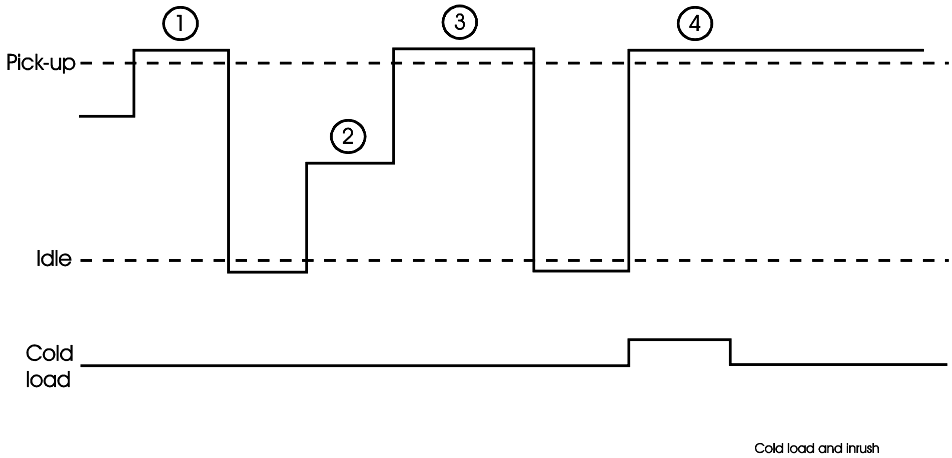
Inrush current detection is quite similar with the cold load detection but it does also include a condition for second harmonic relative content of the currents. When all phase currents have been less than a given idle value and then at least one of them exceeds a given pick-up level within 80 ms and the ratio 2nd harmonic ratio to fundamental frequency, I_{f2}/I_{f1}, of at least one phase exceeds the given setting, the inrush detection signal is activated. This signal is available for output matrix and blocking matrix. Using virtual outputs of the output matrix setting group control is possible.

By setting the Pickupf2 parameter for I_{f2}/I_{f1} to zero, the inrush signal will behave equally with the cold load pick-up signal.

Application for inrush current detection

The inrush current of transformers usually exceeds the pick-up setting of sensitive overcurrent stages and contains a lot of even harmonics. Right after closing a circuit breaker the pick-up and tripping of sensitive overcurrent stages can be avoided by selecting a more coarse setting group for the appropriate over-current stage with inrush detect signal. It is also possible to use the detection signal to block any set of protection stages for a given time.

NOTE! Inrush detection is based on FFT - calculation which recuires full cycle of data for analyzing the harmonic content. Therefore when using inrush blocking function the cold load pick up starting conditions are used for activating the inrush blocking when the current rise is noticed. If in the signal is found second harmonic component after 1.st cycle the blocking is continued, otherwise 2.nd harmonic based blocking signal is released. Inrush blocking is recommended to be used into time delayed overcurrent stages while non blocked instant overcurrent stage is set to 20 % higher than expected inrush current. By this scheme fast reaction time in short circuit faults during the energization can be achieved while time delayed stages are blocked by inrush function.



① No activation because the current has not been under the set I_{dle} current.

② Current dropped under the I_{dle} current level but now it stays between the I_{dle} current and the pick-up current for over 80ms.

③ No activation because the phase two lasted longer than 80ms.

④ Now we have a cold load activation which lasts as long as the operation time was set or as long as the current stays above the pick-up setting.

Figure 6.3-1 Functionality of cold load / inrush current feature.

Parameters of the cold load & inrush detection function

Parameter	Value	Unit	Description	Note
ColdLd	- Start Trip		Status of cold load detection: Cold load situation is active Timeout	
Inrush	- Start Trip		Status of inrush detection: Inrush is detected Timeout	
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
Pickup		A	Primary scaled pick-up value	
Idle		A	Primary scaled upper limit for idle current	
MaxTime		s		Set
Idle		xIGN	Current limit setting for idle situation	Set
Pickup		xIGN	Pick-up setting for minimum start current	Set
	80	ms	Maximum transition time for start recognition	
Pickupf2		%	Pick-up value for relative amount of 2nd harmonic, I_{f2}/I_{f1}	Set

Set = An editable parameter (password needed)

For details of setting ranges see chapter 12.4.

6.4. Voltage sags and swells

The power quality of electrical networks has become increasingly important. The sophisticated loads (e.g. computers etc.) require uninterruptible supply of “clean” electricity. VAMP protection platform provides many power quality functions that can be used to evaluate, monitor and alarm on the basis of the quality. One of the most important power quality functions are voltage sag and swell monitoring.

VAMP provides separate monitoring logs for sags and swells. The voltage log is trigged, if any voltage input either goes under the sag limit (U<) or exceeds the swell limit (U>). There are four registers for both sags and swells in the fault log. Each register will have start time, phase information, duration, minimum, average, maximum voltage values of each sag and swell event. Furthermore, there are total number of sags and swells counters as well as total timers for sags and swells.

The voltage power quality functions are located under the submenu “U”.

Setting parameters of sags and swells monitoring:

Parameter	Value	Unit	Default	Description
U>	20 … 150	%	110	Setting value of swell limit
U<	10 … 120	%	90	Setting value of sag limit
Delay	0.04 … 1.00	s	0.06	Delay for sag and swell detection
SagOn	On; Off	-	On	Sag on event
SagOff	On; Off	-	On	Sag off event
SwelOn	On; Off	-	On	Swell on event
SwelOf	On; Off	-	On	Swell off event

Recorded values of sags and swells monitoring:

	Parameter	Value	Unit	Description
Recorded values	Count		-	Cumulative sag counter
	Total		-	Cumulative sag time counter
	Count		-	Cumulative swell counter
	Total		-	Cumulative swell time counter
Sag/ swell logs 1…4	Date		-	Date of the sag/swell
	Time		-	Time stamp of the sag/swell
	Type		-	Voltage inputs that had the sag/swell
	Time		s	Duration of the sag/swell
	Min1		%Un	Minimum voltage value during the sag/swell in the input 1
	Min2		%Un	Minimum voltage value during the sag/swell in the input 2
	Min3		%Un	Minimum voltage value during the sag/swell in the input 3
	Ave1		%Un	Average voltage value during the sag/swell in the input 1
	Ave2		%Un	Average voltage value during the sag/swell in the input 2
	Ave3		%Un	Average voltage value during the sag/swell in the input 3
	Max1		%Un	Maximum voltage value during the sag/swell in the input 1
	Max2		%Un	Maximum voltage value during the sag/swell in the input 2
	Max3		%Un	Maximum voltage value during the sag/swell in the input 3

For details of setting ranges see chapter 12.4.

6.5. Voltage interruptions

The device includes a simple function to detect voltage interruptions. The function calculates the number of voltage interruptions and the total time of the voltage-off time within a given calendar period. The period is based on the real time clock of the device. The available periods are:

- 8 hours, 00:00 – 08:00, 08:00 – 16:00, 16:00 – 24:00
- one day, 00:00 – 24:00
- one week, Monday 00:00 – Sunday 24:00
- one month, the first day 00:00 – the last day 24:00
- one year, 1st January 00:00 – 31st December 24:00

After each period, the number of interruptions and the total interruption time are stored as previous values. The interruption counter and the total time are cleared for a new period. The old previous values are overwritten.

The voltage interruption is based on the value of the positive sequence voltage U_1 and a user given limit value. Whenever the measured U_1 goes below the limit, the interruption counter is increased, and the total time counter starts increasing.

Shortest recognized interruption time is 40 ms. If the voltage-off time is shorter it may be recognized depending on the relative depth of the voltage dip.

If the voltage has been significantly over the limit U_1< and then there is a small and short under-swing, it will not be recognized (Figure 6.5-1).

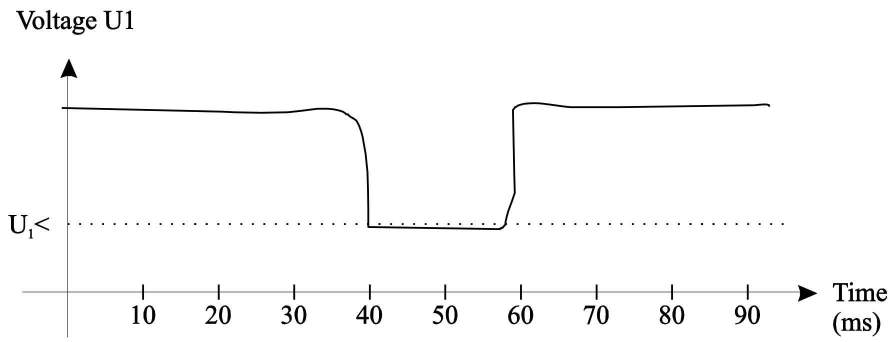


Figure 6.5-1 A short voltage interruption which is probably not recognized

On the other hand, if the limit U_1< is high and the voltage has been near this limit, and then there is a short but very deep dip, it will be recognized (Figure 6.5-2).

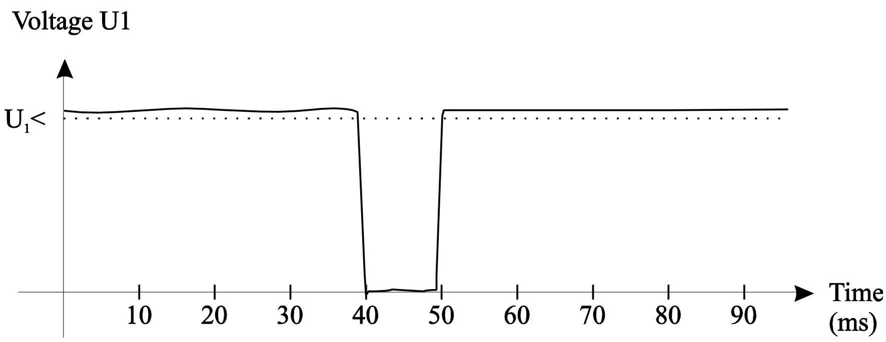


Figure 6.5-2 A short voltage interrupt that will be recognized

Setting parameters of the voltage sag measurement function:

Parameter	Value	Unit	Default	Description
U1<	10.0 … 120.0	%	64	Setting value
Period	8h Day Week Month	-	Month	Length of the observation period
Date		-	-	Date
Time		-	-	Time

Measured and recorded values of voltage sag measurement function:

	Parameter	Value	Unit	Description
Measured value	Voltage	LOW; OK	-	Current voltage status
	U1		%	Measured positive sequence voltage
Recorded values	Count		-	Number of voltage sags during the current observation period
	Prev		-	Number of voltage sags during the previous observation period
	Total		s	Total (summed) time of voltage sags during the current observation period
	Prev		s	Total (summed) time of voltage sags during the previous observation period

For details of setting ranges see chapter 12.4.

6.6. Current transformer supervision

The relay supervise the external wiring between the relay terminals and current transformers (CT) and the CT them selves. Furthermore, this is a safety function as well, since an open secondary of a CT, causes dangerous voltages.

The CT supervisor function measures phase currents. If one of the three phase currents drops below I_{min}< setting, while another phase current is exceeding the I_{max}> setting, the function will issue an alarm after the operation delay has elapsed.

Setting parameters of CT supervisor CTSV ( ):

Parameter	Value	Unit	Default	Description
Imax>	0.0 … 10.0	xIgn	2.0	Upper setting for CT supervisor
Imin<	0.0 … 10.0	xIgn	0.2	Lower setting for CT supervisor
t>	0.02 … 600.0	s	0.10	Operation delay
CT on	On; Off	-	On	CT supervisor on event
CT off	On; Off	-	On	CT supervisor off event

Measured and recorded values of CT supervisor CTSV ( ):

	Parameter	Value	Unit	Description
Measured value	ILmax		A	Maximum of phase currents
	ILmin		A	Minimum of phase currents
Display	Imax>, Imin<		A	Setting values as primary values
Recorded values	Date		-	Date of CT supervision alarm
	Time		-	Time of CT supervision alarm
	Imax		A	Maximum phase current
	Imin		A	Minimum phase current

For details of setting ranges see chapter 12.4.

6.7. Voltage transformer supervision

The device supervises the VTs and VT wiring between the relay terminals and the VTs. If there is a fuse in the voltage transformer circuitry, the blown fuse prevents or distorts the voltage measurement. Therefore, an alarm should be issued. Furthermore, in some applications, protection functions using voltage signals, should be blocked to avoid false tripping.

The VT supervisor function measures the three phase voltages and currents. The negative sequence voltage U_2 and the negative sequence currentI_2 are calculated. If U_2 exceed the U_2> setting and at the same time, I_2 is less than the I_2< setting, the function will issue an alarm after the operation delay has elapsed.

Setting parameters of VT supervisor VTSV ( ):

Parameter	Value	Unit	Default	Description
U2>	0.0 … 200.0	%Un	34.6	Upper setting for VT supervisor
I2<	0.0 … 200.0	%In	100.0	Lower setting for VT supervisor
t>	0.02 … 600.0	s	0.10	Operation delay
VT on	On; Off	-	On	VT supervisor on event
VT off	On; Off	-	On	VT supervisor off event

Measured and recorded values of VT supervisor VTSV ( ):

	Parameter	Value	Unit	Description
Measured value	U2		%Un	Measured negative sequence voltage
	I2		%In	Measured negative sequence current
Recorded values	Date		-	Date of VT supervision alarm
	Time		-	Time of VT supervision alarm
	U2		%Un	Recorded negative sequence voltage
	I2		%In	Recorded negative sequence current

For details of setting ranges see chapter 12.4.

6.8. Circuit breaker condition monitoring

The relay has a condition monitoring function that supervises the wearing of the circuit-breaker. The condition monitoring can give alarm for the need of CB maintenance well before the CB condition is critical.

The CB wear function measures the breaking current of each CB pole separately and then estimates the wearing of the CB accordingly the permissible cycle diagram. The breaking current is registered when the trip relay supervised by the circuit breaker failure protection (CBFP) is activated. (See

chapter 5.25 for CBFP and the setting parameter "CBrelay".)

Breaker curve and its approximation

The permissible cycle diagram is usually available in the documentation of the CB manufacturer (Figure 6.8-1). The diagram specifies the permissible number of cycles for every level of the breaking current. This diagram is parameterised to the condition monitoring function with maximum eight [current, cycles] points. See Table 6.8-1. If less than eight points needed, the unused points are set to [I_{BIG}, 1], where I_{BIG} is more than the maximum breaking capacity.

If the CB wearing characteristics or part of it is a straight line on a log/log graph, the two end points are enough to define that part of the characteristics. This is because the relay is using logarithmic interpolation for any current values falling in between the given current points 2...8.

The points 4...8 are not needed for the CB in Figure 6.8-1. Thus they are set to 100 kA and one operation in the table to be discarded by the algorithm.

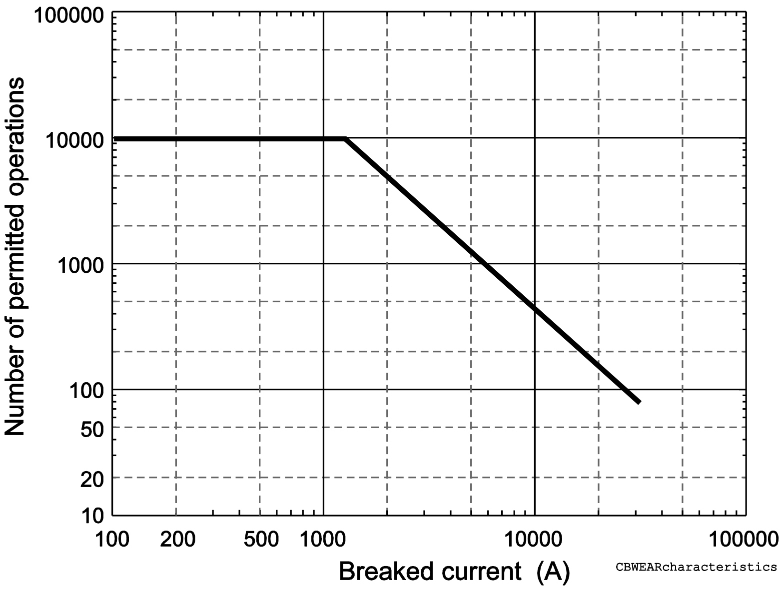


Figure 6.8-1 An example of a circuit breaker wearing characteristic graph.

Table 6.8-1 An example of circuit breaker wearing characteristics in a table format. The value are taken from the

figure above. The table is edited with VAMPSET under menu "BREAKER CURVE".

Point	Interrupted current (kA)	Number of permitted operations
1	0 (mechanical age)	10000
2	1.25 (rated current)	10000
3	31.0 (maximum breaking current)	80
4	100	1
5	100	1
6	100	1
7	100	1
8	100	1

Setting alarm points

There are two alarm points available having two setting parameters each.

- Current.
  The first alarm can be set for example to nominal current of the CB or any application typical current. The second alarm can be set for example according a typical fault current.
- Operations left alarm limit
  An alarm is activated when there are less operation left at the given current level than this limit.

Any actual interrupted current will be logarithmically weighted for the two given alarm current levels and the number of operations left at the alarm points is decreased accordingly. When the "operations left" i.e. the number of remaining operations, goes under the given alarm limit, an alarm signal is issued to the output matrix. Also an event is generated depending on the event enabling.

Clearing "operations left" counters

After the breaker curve table is filled and the alarm currents are defined, the wearing function can be initialised by clearing the decreasing operation counters with parameter "Clear" (Clear oper. left cntrs). After clearing the relay will show the maximum allowed operations for the defined alarm current levels.

Operation counters to monitor the wearing

The operations left can be read from the counters "Al1Ln" (Alarm 1) and "Al2Ln" (Alarm2). There are three values for both alarms, one for each phase. The smallest of three is supervised by the two alarm functions.

Logarithmic interpolation

The permitted number of operations for currents in between the defined points are logarithmically interpolated using equation

Equation 6.8-1

$$C = \frac{a}{I^n}$$, where

C = permitted operations

I = interrupted current

a = constant according Equation 6.8-2

n = constant according Equation 6.8-3

Equation 6.8-2

$$n = \frac{\ln \frac{C_k}{C_{k+1}}}{\ln \frac{I_{k+1}}{I_k}}$$

Equation 6.8-3

$$a = C_k I_k^2$$

ln = natural logarithm function

C_k = permitted operations. k = row 2...7 in Table 6.8-1.

I_k = corresponding current. k = row 2...7 in Table 6.8-1.

C_{k+1} = permitted operations. k = row 2...7 in Table 6.8-1.

I_{k+1} = corresponding current. k = row 2...7 in Table 6.8-1.

Example of the logarithmic interpolation

Alarm 2 current is set to 6 kA. What is the maximum number of operations according Table 6.8-1.

The current 6 kA lies between points 2 and 3 in the table. That gives value for the index k. Using

k = 2

C_k = 10000

C_{k+1} = 80

I_{k+1} = 31 kA

I_k = 1.25 kA

and the Equation 6.8-2 and Equation 6.8-3, the relay calculates

$$n = \frac{\ln \frac{10000}{80}}{\ln \frac{31000}{1250}} = 1.5038$$

$$a = 10000 \cdot 1250^{1.5038} = 454 \cdot 10^6$$

Using Equation 6.8-1 the relay gets the number of permitted operations for current 6 kA.

$$C = \frac{454 \cdot 10^6}{6000^{1.5038}} = 945$$

Thus the maximum number of current breaking at 6 kA is 945. This can be verified with the original breaker curve in Figure 6.8-1. Indeed, the figure shows that at 6 kA the operation count is between 900 and 1000. A useful alarm level for operation-left, could be in this case for example 50 being about five per cent of the maximum.

Example of operation counter decrementing when the CB is breaking a current

Alarm2 is set to 6 kA. CBFP is supervising trip relay T1 and trip signal of an overcurrent stage detecting a two phase fault is connected to this trip relay T1. The interrupted phase currents are 12.5 kA, 12.5 kA and 1.5 kA. How much are Alarm2 counters decremented ?

Using Equation 6.8-1 and values n and a from the previous example, the relay gets the number of permitted operation at 10 kA.

$$C_{10kA} = \frac{454 \cdot 10^6}{12500^{1.5038}} = 313$$

At alarm level 2, 6 kA, the corresponding number of operations is calculated according

Equation 6.8-4

$$\Delta = \frac{C_{AlarmMax}}{C}$$

$$\Delta_{L1} = \Delta_{L2} = \frac{945}{313} = 3$$

Thus Alarm2 counters for phases L1 and L2 are decremented by 3. In phase L1 the currents is less than the alarm limit current 6 kA. For such currents the decrement is one.

$$\Delta_{L3} = 1$$

Local panel parameters of CBWEAR function

Parameter	Value	Unit	Description	Set
CBWEAR STATUS				
 Al1L1 Al1L2 Al1L3 Al2L1 Al2L2 Al2L3			Operations left for - Alarm 1, phase L1 - Alarm 1, phase L2 - Alarm 1, phase L3 - Alarm 2, phase L1 - Alarm 2, phase L2 - Alarm 2, phase L3	
Latest trip				
Date time			Time stamp of the latest trip operation	
IL1 IL2 IL3		A A A	Broken current of phase L1 Broken current of phase L2 Broken current of phase L3	
CBWEAR SET				
Alarm1				
Current	0.00 – 100.00	kA	Alarm1 current level	Set
Cycles	100000 – 1		Alarm1 limit for operations left	Set
Alarm2				
Current	0.00 – 100.00	kA	Alarm2 current level	Set
Cycles	100000 – 1		Alarm2 limit for operations left	Set
CBWEAR SET2				
Al1On	On Off		'Alarm1 on' event enabling	Set
Al1Off	On Off		'Alarm1 off' event enabling	Set
Al2On	On Off		'Alarm2 on' event enabling	Set
Al2Off	On Off		'Alarm2 off' event enabling	Set
Clear	– Clear		Clearing of cycle counters	Set

Set = An editable parameter (password needed)

The breaker curve table is edited with VAMPSET.

6.9. Energy pulse outputs

The device can be configured to send a pulse whenever certain amount of energy has been imported or exported. The principle is presented in Figure 6.9-1. Each time the energy level reaches the pulse size, an output relay is activated and it will stay active as long as defined by a pulse duration setting.

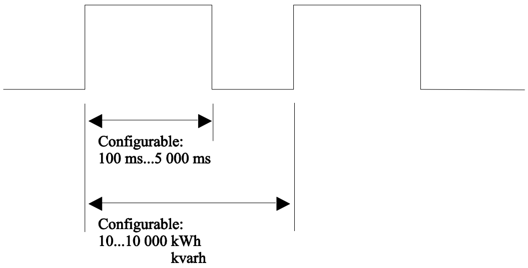


Figure 6.9-1 Principle of energy pulses

The device has four energy pulse outputs. The channels are:

- Active exported energy
- Reactive exported energy
- Active imported energy
- Reactive imported energy

Each channel can be connected to any combination of the output relays using output matrix. The parameters for the energy pulses can be found in the E menu under the submenus E-PULSE SIZES and E-PULSE DURATION.

Energy pulse output parameters

	Parameter	Value	Unit	Description
E-PULSE SIZES	E+	10 … 10 000	kWh	Pulse size of active exported energy
	Eq+	10 … 10 000	kvarh	Pulse size of reactive exported energy
	E-	10 … 10 000	kWh	Pulse size of active imported energy
	Eq-	10 … 10 000	kvarh	Pulse size of reactive imported energy
E-PULSE DURATION	E+	100 … 5000	ms	Pulse length of active exported energy
	Eq+	100 … 5000	ms	Pulse length of reactive exported energy
	E-	100 … 5000	ms	Pulse length of active imported energy
	Eq-	100 … 5000	ms	Pulse length of reactive imported energy

Scaling examples

Example 1.

Average active exported power is 250 MW.

Peak active exported power is 400 MW.

Pulse size is 250 kWh.

The average pulse frequency will be 250/0.250 = 1000 pulses/h.

The peak pulse frequency will be 400/0.250 = 1600 pulses/h.

Set pulse length to 3600/1600 − 0.2 = 2.0 s or less.

The lifetime of the mechanical output relay will be $50x10^6$/1000 h = 6 a.

This is not a practical scaling example unless an output relay lifetime of about six years is accepted.

Example 2.

Average active exported power is 100 MW.

Peak active exported power is 800 MW.

Pulse size is 400 kWh.

The average pulse frequency will be 100/0.400 = 250 pulses/h.

The peak pulse frequency will be 800/0.400 = 2000 pulses/h.

Set pulse length to 3600/2000 − 0.2 = 1.6 s or less.

The lifetime of the mechanical output relay will be $50x10^6$/250 h = 23 a.

Example 3.

Average active exported power is 20 MW.

Peak active exported power is 70 MW.

Pulse size is 60 kWh.

The average pulse frequency will be 25/0.060 = 416.7 pulses/h.

The peak pulse frequency will be 70/0.060 = 1166.7 pulses/h.

Set pulse length to 3600/1167 − 0.2 = 2.8 s or less.

The lifetime of the mechanical output relay will be $50x10^6$/417 h = 14 a.

Example 4.

Average active exported power is 1900 kW.

Peak active exported power is 50 MW.

Pulse size is 10 kWh.

The average pulse frequency will be 1900/10 = 190 pulses/h.

The peak pulse frequency will be 50000/10 = 5000 pulses/h.

Set pulse length to 3600/5000 − 0.2 = 0.5 s or less.

The lifetime of the mechanical output relay will be $50x10^6$/190 h = 30 a.

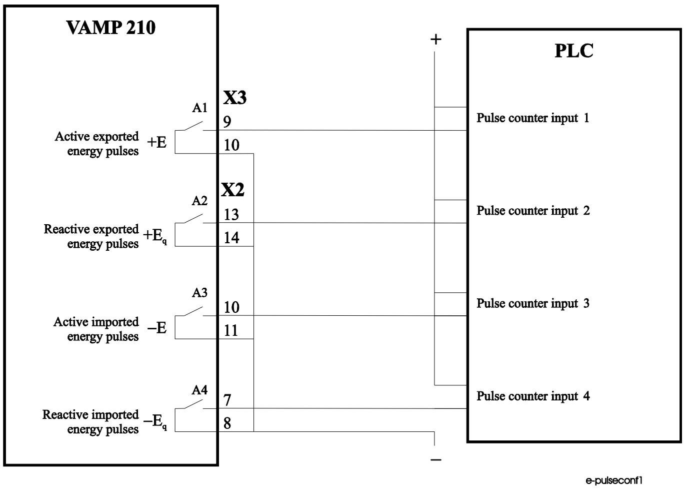


Figure 6.9-2 Application example of wiring the energy pulse outputs to a PLC having common plus and using an external wetting voltage

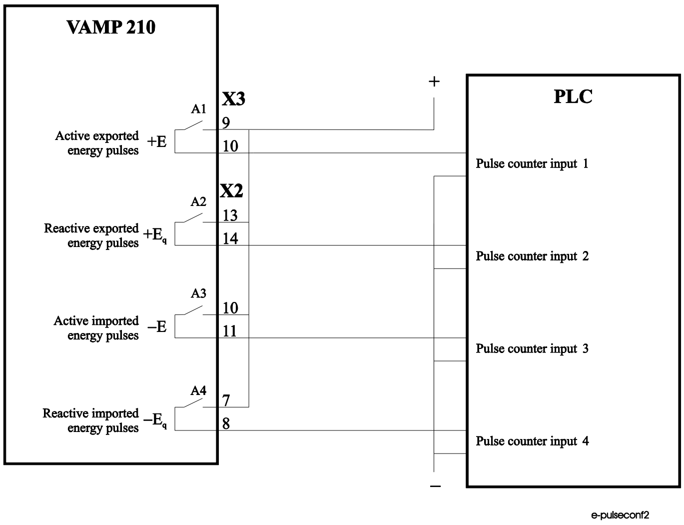


Figure 6.9-3 Application example of wiring the energy pulse outputs to a PLC having common minus and using an external wetting voltage

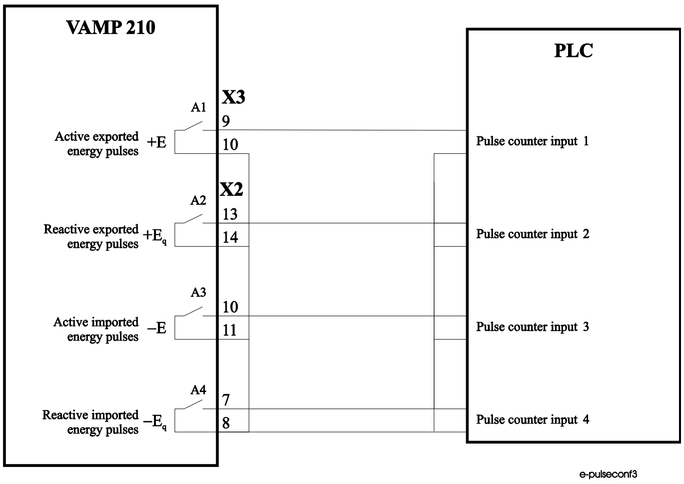


Figure 6.9-4 Application example of wiring the energy pulse outputs to a PLC having common minus and an internal wetting voltage.

6.10. System clock and synchronization

The internal clock of the relay is used to time stamp events and disturbance recordings.

The system clock should be externally synchronised to get comparable event time stamps for all the relays in the system.

The synchronizing is based on the difference of the internal time and the synchronising message or pulse. This deviation is filtered and the internal time is corrected softly towards a zero deviation.

Adapting auto adjust

During tens of hours of synchronizing the device will learn its average error and starts to make small corrections by itself. The target is that when the next synchronizing message is received, the deviation is already near zero. Parameters "AAIntv" and "AvDrft" will show the adapted correction time interval of this ±1 ms auto-adjust function.

Time drift correction without external sync

If any external synchronizing source is not available and the system clock has a known steady drift, it is possible to roughly correct the clock error by editing the parameters "AAIntv" and "AvDrft". The following equation can be used if the previous "AAIntv" value has been zero.

$$AAIntv = \frac{604.8}{DriftInOneWeek}$$

If the auto-adjust interval "AAIntv" has not been zero, but further trimming is still needed, the following equation can be used to calculate a new auto-adjust interval.

$$AAIntv_{NEW} = \frac{1}{\frac{1}{AAIntv_{PREVIOUS}} + \frac{DriftInOneWeek}{604.8}}$$

The term $DriftInOneWeek/604.8$ may be replaced with the relative drift multiplied by 1000, if some other period than one week has been used. For example if the drift has been 37 seconds in 14 days, the relative drift is 37*1000/(14*24*3600) = 0.0306 ms/s.

Example 1.

If there has been no external sync and the relay's clock is leading sixty-one seconds a week and the parameter AAIntv has been zero, the parameters are set as

$$AvDrft = Lead$$

$$AAIntv = \frac{604.8}{61} = 9.9s$$

With these parameter values the system clock corrects itself with –1 ms every 9.9 seconds which equals –61.091 s/week.

Example 2.

If there is no external sync and the relay's clock has been lagging five seconds in nine days and the AAIntv has been 9.9 s, leading, then the parameters are set as

$$AAIntv_{NEW} = \frac{1}{\frac{1}{9.9} - \frac{5000}{9 \cdot 24 \cdot 3600}} = 10.6$$

$$AvDrft = Lead$$

NOTE! When the internal time is roughly correct – deviation is less than four seconds – any synchronizing or auto-adjust will never turn the clock backwards. Instead, in case the clock is leading, it is softly slowed down to maintain causality.

System clock parameters

Parameter	Value	Unit	Description	Note
Date			Current date	Set
Time			Current time	Set
Style 	 y–d–m d.m.y m/d/y		Date format Year-Month-Day Day.Month.Year Month/Day/Year	Set
SyncDI	 – DI1 ... DI6		The digital input used for clock synchronisation. DI not used for synchronizing Minute pulse input	***)
TZone	–12.00 ... +14.00 *)		UTC time zone for SNTP synchronization. Note: This is a decimal number. For example for state of Nepal the time zone 5:45 is given as 5.75	Set
DST	No Yes		Daylight saving time for SNTP	Set

Parameter	Value	Unit	Description	Note

SySrc 	 Internal DI SNTP SpaBus ModBus ProfibusDP IEC-103 DNP3		Clock synchronisation source No sync recognized since 200 s Digital input Protocol sync Protocol sync Protocol sync Protocol sync Protocol sync Protocol sync	
MsgCnt	0 ... 65535, 0 ... etc.		The number of received synchronisation messages or pulses	
Dev	±32767	ms	Latest time deviation between the system clock and the received synchronization	
SyOS	±10000.000	s	Synchronisation correction for any constant error in the synchronizing source. A positive value will compensate a lagging external sync and communication delays. A negative value will compensate any leading offset of the external synch source.	Set
AAIntv	±10000	s	Adapted auto adjust interval for 1 ms correction	Set**)
AvDrft	Lead Lag		Adapted average clock drift sign	Set **)
FilDev	±125	ms	Filtered synchronisation deviation	

Set = An editable parameter (password needed).

*) Astronomically a range –11 ... +12 h would be enough, but for political and geographical reasons a larger range is needed.

**) If external synchoronization is used this parameter will be set automatically.

***) Set the DI delay to its minimum and the polarity such that the leading edge is the synchronizing edge.

6.11. Running hour counter

This function calculates the total active time of the selected digital input, virtual I/O or output matrix output signal. The resolution is ten seconds.

Running hour counter parameters

Parameter	Value	Unit	Description	Note
Runh	0 ... 876000	h	Total active time, hours Note: The label text "Runh" can be edited with VAMPSET.	(Set)
	0 ... 3599	s	Total active time, seconds	(Set)
Starts	0 ... 65535		Activation counter	(Set)
Status	Stop Run		Current status of the selected digital signal	
DI	 - DI1 ...DI6, VI1...VI4, LedAl, LedTr, LedA, LedB, LedC, LedDR VO1...VO6		Select the supervised signal None Physical inputs Virtual inputs Output matrix out signal Al Output matrix out signal Tr Output matrix out signal LA Output matrix out signal LB Output matrix out signal LC Output matrix out signal DR Virtual outputs	Set
Started at			Date and time of the last activation	
Stopped at			Date and time of the last inactivation	

Set = An editable parameter (password needed).

(Set) = An informative value which can be edited as well.

6.12. Timers

The VAMP protection platform includes four settable timers that can be used together with the user's programmable logic or to control setting groups and other applications that require actions based on calendar time. Each timer has its own settings. The selected on-time and off-time is set and then the activation of the timer can be set to be as daily or according the day of week (See the setting parameters for details). The timer outputs are available for logic functions and for the block and output matrix.

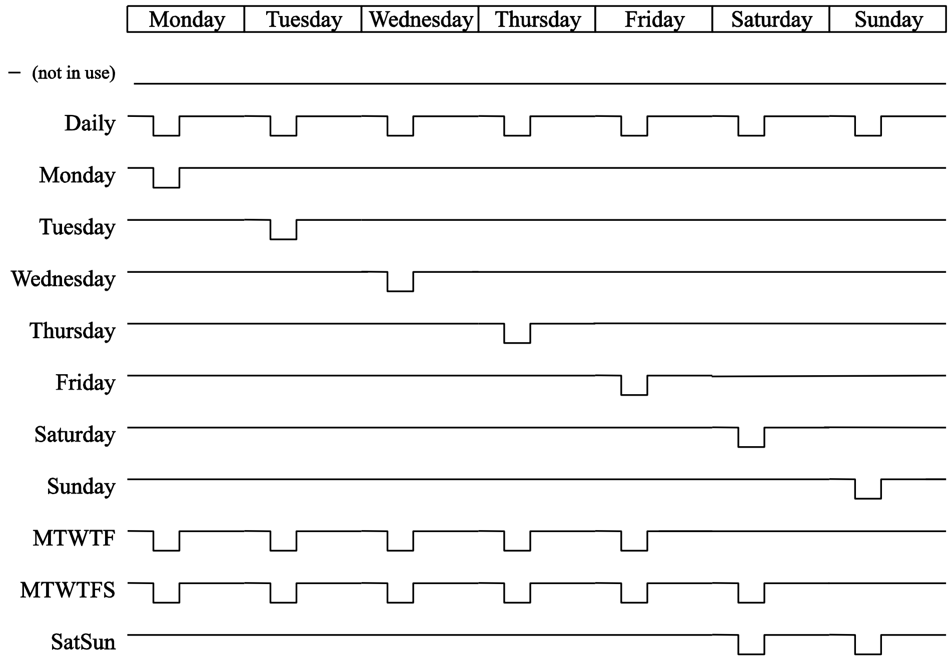


Figure 6.12-1 Timer output sequence in different modes.

The user can force any timer, which is in use, on or off. The forcing is done by writing a new status value. No forcing flag is needed as in forcing i.e. the output relays.

The forced time is valid until the next forcing or until the next reversing timed act from the timer itself.

The status of each timer is stored in non-volatile memory when the auxiliary power is switched off. At start up, the status of each timer is recovered.

Setting parameters of timers

Parameter	Value	Description
TimerN		Timer status
	–	Not in use
	0	Output is inactive
	1	Output is active
On	hh:mm:ss	Activation time of the timer
Off	hh:mm:ss	De-activation time of the timer
Mode		For each four timers there are 12 different modes available:
	–	The timer is off and not running. The output is off i.e. 0 all the time.
	Daily	The timer switches on and off once every day.
	Monday	The timer switches on and off every Monday.
	Tuesday	The timer switches on and off every Tuesday.
	Wednesday	The timer switches on and off every Wednesday.
	Thursday	The timer switches on and off every Thursday.
	Friday	The timer switches on and off every Friday.
	Saturday	The timer switches on and off every Saturday.
	Sunday	The timer switches on and off every Sunday.
	MTWTF	The timer switches on and off every day except Saturdays and Sundays
	MTWTFS	The timer switches on and off every day except Sundays.
	SatSun	The timer switches on and off every Saturday and Sunday.

6.13. Combined overcurrent status

This function is collecting faults, fault types and registered fault currents of all enabled overcurrent stages.

Line fault parameters

Parameter	Value	Unit	Description	Note
IFltLas		xI_{GN}	Current of the latest overcurrent fault	(Set)
LINE ALARM				
AlrL1 AlrL2 AlrL3	 0 1		Start (=alarm) status for each phase. 0=No start since alarm ClrDly 1=Start is on	
OCs	 0 1		Combined overcurrent start status. AlrL1=AlrL2=AlrL3=0 AlrL1=1 orAlrL2=1 or AlrL3=1	
LxAlarm	 On Off		'On' Event enabling for AlrL1...3 Events are enabled Events are disabled	Set
LxAlarmOff	 On Off		'Off' Event enabling for AlrL1...3 Events are enabled Events are disabled	Set
OCAlarm	 On Off		'On' Event enabling for combined o/c starts Events are enabled Events are disabled	Set
OCAlarmOff	 On Off		'Off' Event enabling for combined o/c starts Events are enabled Events are disabled	Set
IncFltEvnt	 On Off		Disabling several start and trip events of the same fault Several events are enabled *) Several events of an increasing fault is disabled **)	Set
ClrDly	0 ... 65535	s	Duration for active alarm status AlrL1, Alr2, AlrL3 and OCs	Set

Parameter	Value	Unit	Description	Note
LINE FAULT				
FltL1 FltL2 FltL3	 0 1		Fault (=trip) status for each phase. 0=No fault since fault ClrDly 1=Fault is on	
OCt	 0 1		Combined overcurrent trip status. FltL1=FltL2=FltL3=0 FltL1=1 orFltL2=1 or FltL3=1	
LxTrip	 On Off		'On' Event enabling for FltL1...3 Events are enabled Events are disabled	Set
LxTripOff	 On Off		'Off' Event enabling for FltL1...3 Events are enabled Events are disabled	Set
OCTrip	 On Off		'On' Event enabling for combined o/c trips Events are enabled Events are disabled	Set
OCTripOff	 On Off		'Off' Event enabling for combined o/c starts Events are enabled Events are disabled	Set
IncFltEvnt	 On Off		Disabling several events of the same fault Several events are enabled *) Several events of an increasing fault is disabled **)	Set
ClrDly	0 ... 65535	s	Duration for active alarm status FltL1, Flt2, FltL3 and OCt	Set

Set = An editable parameter (password needed)

*) Used with IEC 60870-105-103 communication protocol. The alarm screen will show the latest if it's the biggest registered fault current, too. Not used with Spabus, because Spabus masters usually don't like to have unpaired On/Off events.

**) Used with SPA-bus protocol, because most SPA-bus masters do need an off-event for each corresponding on-event.

6.14. Self-supervision

The functions of the micro controller and the associated circuitry, as well as the program execution are supervised by means of a separate watchdog circuit. Besides supervising the relay, the watchdog circuit attempts to restart the micro controller in a fault situation. If the restarting fails, the watchdog issues a self-supervision alarm indicating a permanent internal fault.

When the watchdog circuit detects a permanent fault, it always blocks any control of other output relays (except for the self-supervision output relay).

In addition, the internal supply voltages are supervised. Should the auxiliary supply of the relay disappear, an alarm is automatically given because the internal fault (IF) output relay functions on a working current principle. This means that the IF relay is energized when the auxiliary supply is on and no internal fault is detected.

7. Measurement functions

All the direct measurements are based on fundamental frequency values. (The exceptions are frequency and instantaneous current for arc protection.) The figure shows a current waveform and the corresponding fundamental frequency component, second harmonic and rms value in a special case, when the current deviates significantly from a pure sine wave.

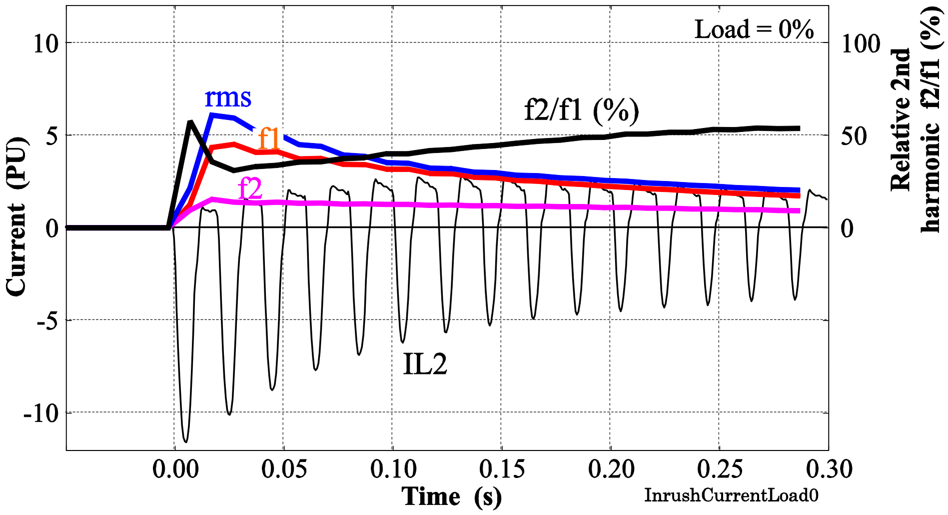


Figure 7-1 Example of various current values of a transformer inrush current.

7.1. Measurement accuracy

The specified frequency range for all measurements except frequency is 45 Hz – 65 Hz.

Phase current inputs I_{L1}, I_{L2}, I_{L3}

Measuring range		25mA – 250 A (5A) 5mA – 50 A (1A)
Inaccuracy	I ≤ 7.5 A	±0.5 % of value or ±0.3 % of I_N
	I > 7.5 A	±3 % of value
Squelch level		0.001 x I_N

The rated input I_N is 5 A or 1 A. It is specified in the order code of the relay.

Voltage inputs U_a, U_b, U_c

The usage of voltage inputs depends on the configuration parameter voltage measurement mode (chapter 7.6). For example, U_c is the input for zero sequence voltage U_0 if the mode "2LL + U_0" is selected but in mode "3LN" the same input is used for phase-to-neutral voltage U_{L3}.

Measuring range	0 – 160 V
Inaccuracy	±0.5 % or ±0.3 V
Squelch level	0.1 V

Residual current inputs I_{01}, I_{02}

Measuring range		0 – 5 xI_{0N}
Inaccuracy	I ≤ 1.5 xI_{0N}	±0.5 % of value or ±0.3 % of I_{0N}
	I > 1.5 xI_{0N}	±3 % of value
Squelch level		0.0002 x I_{0N}

The rated input I_{0N} is 5A, 1 A or 0.2 A. It is specified in the order code of the relay.

Frequency

Measuring range	16 Hz – 75 Hz
Inaccuracy	±10 mHz

The frequency is measured from voltage inputs U_a and/or U_b.

Power measurements P, Q, S

Inaccuracy	|PF|> 0.5	±1 % of value or ±3 VA_{SEC}

Power factor, cosφ, tanφ

Inaccuracy	|PF|>0.5	±2° or ±0.02

Energy counters E+, Eq+, E-, Eq-

Inaccuracy	|PF| > 0.5	±1 % of value or ±3 $Wh_{secondary}$/1 h

THD and harmonics

Inaccuracy	I, U > 0.1 PU	±2 % units
Update rate		At least once a second

7.2. Harmonics and Total Harmonic Distortion (THD)

The device calculates the THDs as percentage of the base frequency for currents and voltages.

The device calculates the harmonics from the 2nd to the 15th of phase currents and voltages. (The 17th harmonic component will also be shown partly in the value of the 15th harmonic component. This is due to the nature of digital sampling.)

The harmonic distortion is calculated using equation

$$THD = \frac{\sqrt{\sum_{i=2}^{15} h_i^2}}{h_1}$$, where

h_1 = Fundamental value

$h_{2...15}$ = Harmonics

Example

h_1 = 100 A

h_3 = 10 A

h_7 = 3 A

h_{11} = 8 A

$$THD = \frac{\sqrt{10^2 + 3^2 + 8^2}}{100} = 13.2\%$$

For reference the RMS value is:

$$RMS = \sqrt{100^2 + 10^2 + 3^2 + 8^2} = 100.9A$$

Another way to calculate THD is to use the RMS value as reference instead of the fundamental frequency value. In the example above the result would then be 13.0 %.

7.3. Demand values

The relay calculates average i.e. demand values of phase currents I_{L1}, I_{L2}, I_{L3} and power values S, P and Q. The demand time is configurable from 10 minutes to 30 minutes with parameter "Demand time".

Demand value parameters

Parameter	Value	Unit	Description	Set
Time	10 ... 30	min	Demand time (averaging time)	Set
Fundamental frequency values				
IL1da		A	Demand of phase current IL1	
IL2da		A	Demand of phase current IL2	
IL3da		A	Demand of phase current IL3	
Pda		kW	Demand of active power P	
PFda			Demand of power factor PF	
Qda		kvar	Demand of reactive power Q	
Sda		kVA	Demand of apparent power S	
RMS values				
IL1da		A	Demand of phase current IL1	
IL2da		A	Demand of phase current IL2	
IL3da		A	Demand of phase current IL3	

7.4. Minimum and maximum values

Minimum and maximum values are registered with time stamps since the latest manual clearing or since the device has been restarted. The available registered min & max values are listed in the following table.

Min & Max measurement	Description
IL1, IL2, IL3	Phase current (fundamental frequency value)
IL1RMS, IL2RMS, IL3RMS	Phase current, rms value
Io1, Io2	Residual current
U12, U23, U31	Line-to-line voltage
Uo	Zero sequence voltage
f	Frequency
P, Q, S	Active, reactive, apparent power
IL1da, IL2da, IL3da	Demand values of phase currents
IL1da, IL2da, IL3da (rms value)	Demand values of phase currents, rms values
PFda	Power factor demand value

The clearing parameter "ClrMax" is common for all these values.

Parameters

Parameter	Value	Description	Set
ClrMax	– Clear	Reset all minimum and maximum values	S

7.5. Maximum values of the last 31 days and twelve months

Some maximum and minimum values of the last 31 days and the last twelve months are stored in the non-volatile memory of the relay. Corresponding time stamps are stored for the last 31 days. The registered values are listed in the following table.

Measurement	Max	Min	Description
IL1, IL2, IL3	X		Phase current (fundamental frequency value)
Io1, Io2	X		Residual current
S	X		Apparent power
P	X	X	Active power
Q	X	X	Reactive power

The value can be a one cycle value or an average according parameter "Timebase".

Parameters of the day and month registers

Parameter	Value	Description	Set
Timebase		Parameter to select the type of the registered values.	S
	20 ms	Collect min & max of one cycle values *)	
	200 ms	Collect min & max of 200 ms average values	
	1 s	Collect min & max of 1 s average values	
	1 min	Collect min & max of 1 minute average values	
	demand	Collect min & max of demand values (see chapter 7.3)	
ResetDays		Reset the 31 day registers	S
ResetMon		Reset the 12 month registers	S

*) This is the fundamental frequency rms value of one cycle updated every 20 ms.

7.6. Voltage measurement mode

Depending on the application and available voltage transformers, the relay can be connected either to line-to-line voltages or phase-to-ground voltages. The configuration parameter "Voltage measurement mode" must be set according the used connection.

The available modes are:

- "2LL+Uo"
  The device is connected to line-to-line voltages U_{12} and U_{23} and to zero sequence voltage U_0. The phase-to-ground voltages are calculated. See Figure 7.6-1 and Figure 7.6-2. The network must use only three wires. Any neutral wire must not exist.
- "3LN"
  The device is connected to phase-to-ground voltages U_{L1}, U_{L2} and U_{L3}. The zero sequence voltage is calculated. See Figure 7.6-3. There may exist a neutral wire.

The overvoltage protection is always based on the line-to-line voltage regardless of the measurement mode.

NOTE! When the 100 % stator earth fault stage U0f3< is to be used, the mode "2LL+Uo" must be used and the zero sequence voltage must be measured from the generator's neutral point as in Error! Reference source not found.**.**

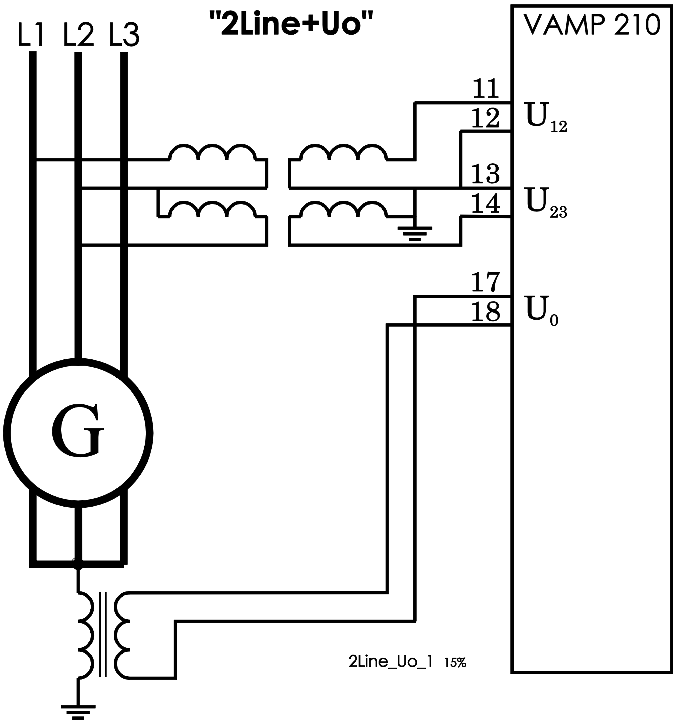


Figure 7.6-1 The device is connected to line-to-line voltages from V-connected (open delta) voltage transformers. The zero sequence voltage is measured with a voltage transformer between neutral point and ground. Voltage measurement mode is set to "2LL+U_0".

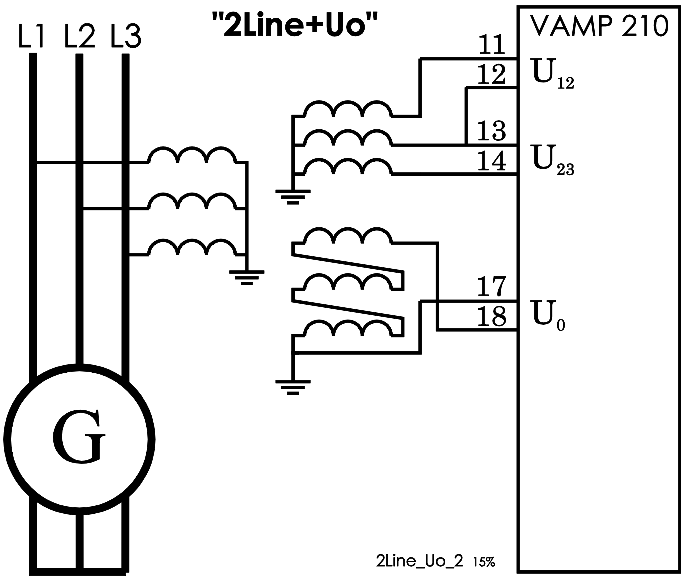


Figure 7.6-2 The device is connected to line-to-line voltages from three Y-connected voltage transformers. The zero sequence voltage is measured with VT tertiaries in a broken delta connection. Voltage measurement mode is set to "2LL+U_0".

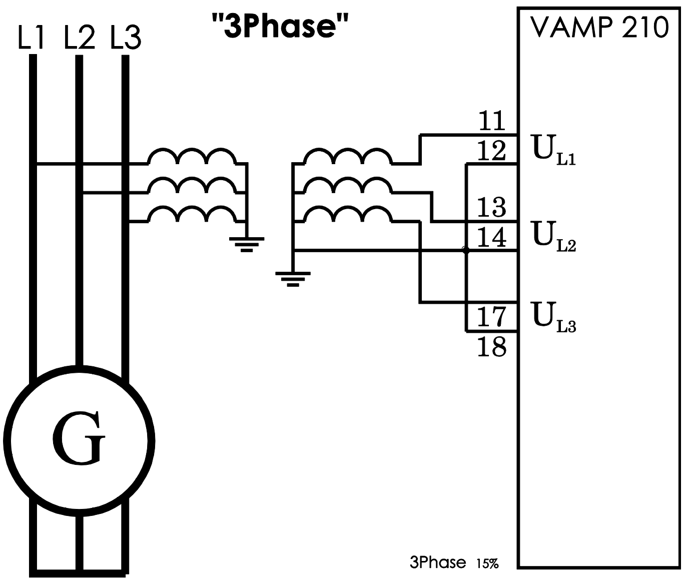


Figure 7.6-3 The device is connected to phase-to-ground voltages from three Y-connected voltage transformers. The zero sequence is calculated internally. Voltage measurement mode is set to "3LN".

7.7. Power calculation

The power calculation in VAMP relays are dependent on the voltage measurement mode, see chapter 7.6. The equations used for power calculations are described in this chapter.

The relay is connected to line-to-line voltages

When the relay is connected to line-to-line voltages, the voltage measurement mode is set to equal to "2LL+Uo". The following Aron equation is used for power calculation.

$\overline{S} = \overline{U}_{12} \cdot \overline{I}_{L1}^{*} - \overline{U}_{23} \cdot \overline{I}_{L3}^{*}$, where

$\overline{S}$	=	Three phase power phasor
$\overline{U}_{12}$	=	Measured voltage phasor corresponding the fundamental frequency voltage between phases L1 and L2.
$\overline{I}_{L1}^{*}$	=	Complex conjugate of the measured phase L1 fundamental frequency current phasor.
$\overline{U}_{23}$	=	Measured voltage phasor corresponding the fundamental frequency voltage between phases L2 and L3.
$\overline{I}_{L3}^{*}$	=	Complex conjugate of the measured phase L3 fundamental frequency current phasor.

Apparent power, active power and reactive power are calculated as follows

$$S = \left|\overline{S}\right|$$

$$P = real(\overline{S})$$

$$Q = imag(\overline{S})$$

$$\cos\varphi = \frac{P}{S}$$

The relay is connected to line-to-neutral voltage

When the relay is connected to line-to-neutral voltages, the voltage measurement mode is set to equal to "3LN". The following equation is used for power calculation.

$\overline{S} = \overline{U}_{L1} \cdot \overline{I}^{*}_{L1} + \overline{U}_{L2} \cdot \overline{I}^{*}_{L2} + \overline{U}_{L3} \cdot \overline{I}^{*}_{L3}$, where

$\overline{S}$	=	Three phase power phasor
$\overline{U}_{L1}$	=	Measured voltage phasor corresponding the fundamental frequency voltage of phase L1.
$\overline{I}^{*}_{L1}$	=	Complex conjugate of the measured phase L1 fundamental frequency current phasor.
$\overline{U}_{L2}$	=	Measured voltage phasor corresponding the fundamental frequency voltage of phase L2.
$\overline{I}^{*}_{L2}$	=	Complex conjugate of the measured phase L2 fundamental frequency current phasor.
$\overline{U}_{L3}$	=	Measured voltage phasor corresponding the fundamental frequency voltage of phase L3.
$\overline{I}^{*}_{L3}$	=	Complex conjugate of the measured phase L3 fundamental frequency current phasor.

Apparent power, active power and reactive power are calculated similarly as with line-to-line voltages

$$S = \left|\overline{S}\right|$$

$$P = real(\overline{S})$$

$$Q = imag(\overline{S})$$

$$\cos\varphi = \frac{P}{S}$$

7.8. Direction of power and current

Figure 7.8-1 shows the concept of three phase current direction and sign of cosφ and power factor PF. Figure 7.8-2 shows the same concepts, but on a PQ-power plane.

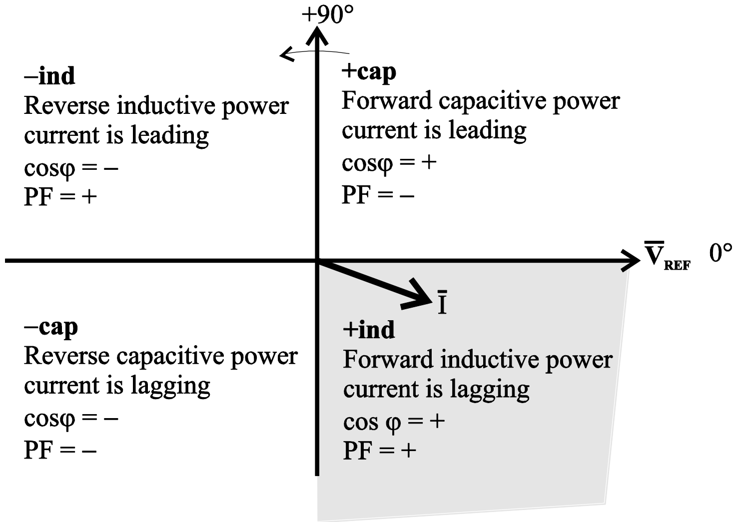


Figure 7.8-1 Quadrants of voltage/current phasor plane

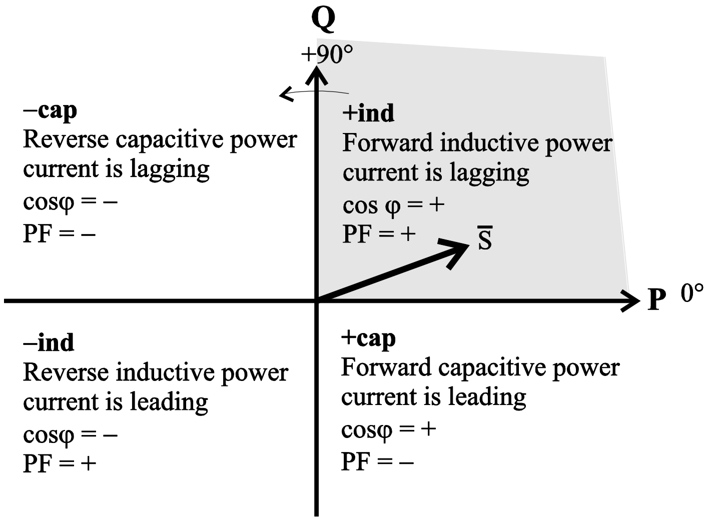


Figure 7.8-2 Quadrants of power plane

Table of power quadrants

Power quadrant	Current related to voltage	Power direction	cosφ	Power factor PF
+ inductive	Lagging	Forward	+	+
+ capacitive	Leading	Forward	+	–
– inductive	Leading	Reverse	–	+
– capacitive	Lagging	Reverse	–	–

7.9. Symmetric components

In a three phase system, the voltage or current phasors may be divided in symmetric components according C. L. Fortescue (1918). The symmetric components are:

- Positive sequence 1
- Negative sequence 2
- Zero sequence 0

Symmetric components are calculated according the following equations:

$$\begin{bmatrix} \underline{S}_0 \\ \underline{S}_1 \\ \underline{S}_2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \underline{a} & \underline{a}^2 \\ 1 & \underline{a}^2 & \underline{a} \end{bmatrix} \begin{bmatrix} \underline{U} \\ \underline{V} \\ \underline{W} \end{bmatrix}$$, where

$\underline{S}_0$ = zero sequence component

$\underline{S}_1$ = positive sequence component

$\underline{S}_2$ = negative sequence component

$\underline{a} = 1\angle 120° = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$, a phasor rotating constant

$\underline{U}$ = phasor of phase L1 (phase current or line-to-neutral voltage)

$\underline{V}$ = phasor of phase L2

$\underline{W}$ = phasor of phase L3

In case the voltage measurement mode is "2LL+Uo" i.e. two line-to-line voltage are measured, the following equation is used instead.

$$\begin{bmatrix} \underline{U}_1 \\ \underline{U}_2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & -\underline{a}^2 \\ 1 & -\underline{a} \end{bmatrix} \begin{bmatrix} \underline{U}_{12} \\ \underline{U}_{23} \end{bmatrix}$$, where

U_{12} = Voltage between phases L1 and L2.

U_{23} = Voltage between phases L2 and L3.

When using line-to-line voltages, any zero sequence voltage can not be calculated.

NOTE! The zero sequence or residual measurement signals connected to the relay are $-U_0$ and $3I_0$. However, usually the name "I_0" is used instead of the correct name "$3I_0$"

Example 1, single phase injection

U_{GN} = 100 V

Voltage measurement mode is "2LL+Uo".

Injection:

U_a = U_{12} = 100 V

U_b = U_{23} = 0

$$\begin{bmatrix} \underline{U}_1 \\ \underline{U}_2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & -\underline{a}^2 \\ 1 & -\underline{a} \end{bmatrix}\begin{bmatrix} 100\angle 0^\circ \\ 0 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 100\angle 0^\circ \\ 100\angle 0^\circ \end{bmatrix} = \begin{bmatrix} 33 \\ 33 \end{bmatrix}$$

U_1 = 33 %

U_2 = 33 %

U_2/U_1 = 100 %

When using a single phase test device, the relative unbalance U_2/U_1 will always be 100 %.

Example 2, two phase injection with adjustable phase angle

U_{GN} = 100 V

Voltage measurement mode is "2LL+Uo".

Injection:

U_a = U_{12} = 100 V $\angle 0°$

U_b = U_{23} = 100/√3 V $\angle$–150° = 57.7 V $\angle$–150°

$$\begin{bmatrix} \underline{U}_1 \\ \underline{U}_2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & -\underline{a}^2 \\ 1 & -\underline{a} \end{bmatrix}\begin{bmatrix} 100\angle 0^\circ \\ 100/\sqrt{3}\angle -150^\circ \end{bmatrix} = \frac{100}{3}\begin{bmatrix} 1\angle 0^\circ - 1/\sqrt{3}\angle +90^\circ \\ 1\angle 0^\circ - 1/\sqrt{3}\angle -30^\circ \end{bmatrix} =$$

$$= \frac{100}{3}\begin{bmatrix} 2/\sqrt{3}\angle -30^\circ \\ 1/\sqrt{3}\angle +30^\circ \end{bmatrix} = \begin{bmatrix} 38.5\angle -30^\circ \\ 19.2\angle +30^\circ \end{bmatrix}$$

U_1 = 38.5 %

U_2 = 19.2 %

U_2/U_1 = 50 %

Figure 7.9-1 shows a geometric solution. The input values have been scaled with √3/100 to make the calculation easier.

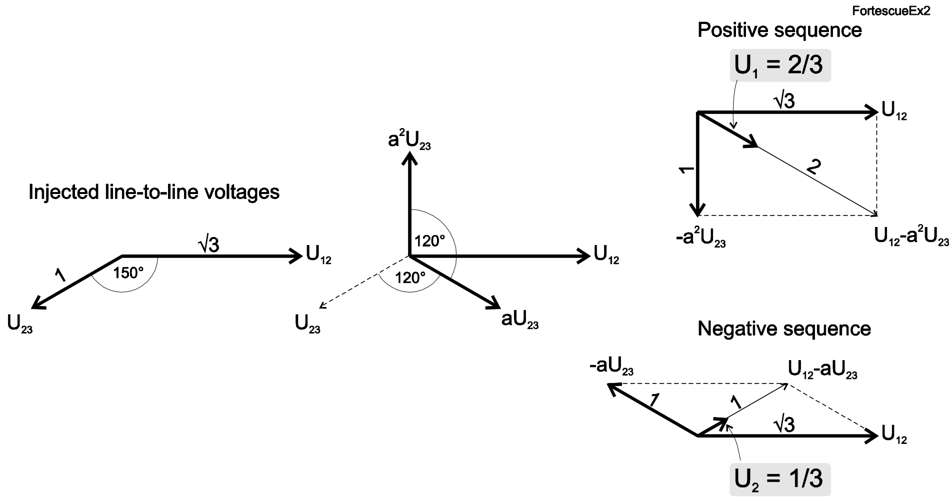


Figure 7.9-1 Example of symmetric component calculation using line-to-line voltages.

Unscaling the geometric results gives

U_1 = 100/√3 x 2/3 = 38.5 %

U_2 = 100/√3 x 1/3 = 19.2 %

U_2/U_1 = 1/3:2/3 = 50 %

Example 3, two phase injection with adjustable phase angle

U_{GN} = 100 V

Voltage measurement mode is "3LN".

Injection:

U_a = U_{L1} = 100/√3 V ∠0° = 57.7 V ∠0°

U_b = U_{L2} = 100/√3 V ∠–120° = 57.7 V ∠–120°

U_c = U_{L3} = 0 V

This is actually identical case with example 2 because the resulting line-to-line voltages $U_{12} = U_{L1} - U_{L2}$ = 100 V ∠30° and $U_{23} = U_{L2} - U_{L3} = U_{L2}$ = 100/√3 V∠–120° are the same as in example 2. The only difference is a +30° phase angle difference, but without any absolute angle reference this phase angle difference is not seen by the device.

$$\begin{bmatrix}\underline{U}_0\\ \underline{U}_1\\ \underline{U}_2\end{bmatrix}=\frac{1}{3}\begin{bmatrix}1 & 1 & 1\\ 1 & \underline{a} & \underline{a}^2\\ 1 & \underline{a}^2 & \underline{a}\end{bmatrix}\begin{bmatrix}\frac{100}{\sqrt{3}}\angle 0^\circ\\ \frac{100}{\sqrt{3}}\angle -120^\circ\\ 0\end{bmatrix}=\frac{1}{3\sqrt{3}}\begin{bmatrix}100\angle 0^\circ+100\angle -120^\circ\\ 100\angle 0^\circ+100\angle 0^\circ\\ 100\angle 0^\circ+100\angle +120^\circ\end{bmatrix}=$$

$$=\frac{1}{3\sqrt{3}}\begin{bmatrix}100\angle -60^\circ\\ 200\angle 0^\circ\\ 100\angle 60^\circ\end{bmatrix}=\begin{bmatrix}19.2\angle -60^\circ\\ 38.5\angle 0^\circ\\ 19.2\angle +60^\circ\end{bmatrix}$$

U_0 = 19.2 %
U_1 = 38.5 %
U_2 = 19.2 %
U_2/U_1 = 50 %

Figure 7.9-2 shows a graphical solution. The input values have been scaled with √3/100 to make the calculation easier.

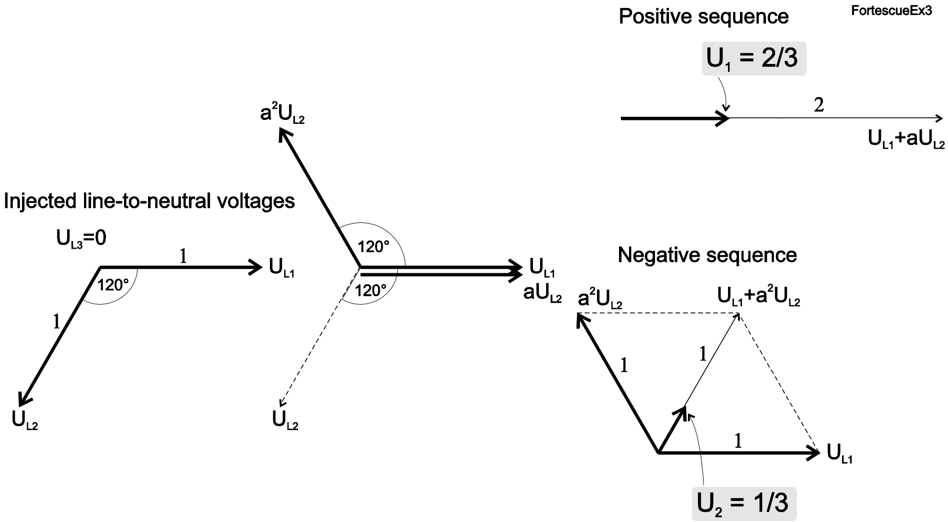


Figure 7.9-2 Example of symmetric component calculation using line-to-neutral voltages.

Unscaling the geometric results gives
U_1 = 100/√3 x 2/3 = 38.5 %
U_2 = 100√3 x 1/3 = 19.2 %
U_2/U_1 = 1/3:2/3 = 50 %

7.10. Primary, secondary and per unit scaling

Many measurement values are shown as primary values although the relay is connected to secondary signals. Some measurement values are shown as relative values - per unit or per cent. Almost all pick-up setting values are using relative scaling. The scaling is done using the given CT, VT and generator name plate values.

The following scaling equations are useful when doing secondary testing.

7.10.1. Current scaling

NOTE! The rated value of the relay's current input, 5 A or 1A , does not have any effect in the scaling equations, but it defines the measurement range and the maximum allowed continuous current. See chapter 12.1.1 for details.

Primary and secondary scaling

	Current scaling
secondary ⇒ primary	$I_{PRI} = I_{SEC} \cdot \frac{CT_{PRI}}{CT_{SEC}}$
primary ⇒ secondary	$I_{SEC} = I_{PRI} \cdot \frac{CT_{SEC}}{CT_{PRI}}$

For residual currents to inputs I_{01} or I_{02} use the corresponding CT_{PRI} and CT_{SEC} values. For earth fault stages using I_{0Calc} signals use the phase current CT values for CT_{PRI} and CT_{SEC}.

Example 1: Secondary to primary.

CT = 500/5

Current to the relay's input is 4 A.

⇒ Primary current is I_{PRI} = 4x500/5 = 400 A

Example 2: Primary to secondary.

CT = 500/5

The relay displays I_{PRI} = 400 A

⇒ Injected current is I_{SEC} = 400x5/500 = 4 A

Per unit [pu] scaling

For phase currents excluding ArcI> stage
1 pu = 1xI_{GN} = 100 %, where
I_{GN} is the rated current of the generator.

For residual currents and ArcI> stage
1 pu = 1xCT_{SEC} for secondary side and
1 pu = 1xCT_{PRI} for primary side.

	Phase current scaling excluding ArcI> stage	**Residual current ($3I_0$) scaling and phase current scaling for ArcI> stage**
secondary ⇒ per unit	$I_{PU} = \frac{I_{SEC} \cdot CT_{PRI}}{CT_{SEC} \cdot I_{GN}}$	$I_{PU} = \frac{I_{SEC}}{CT_{SEC}}$
per unit ⇒ secondary	$I_{SEC} = I_{PU} \cdot CT_{SEC} \cdot \frac{I_{GN}}{CT_{PRI}}$	$I_{SEC} = I_{PU} \cdot CT_{SEC}$

Example 1: Secondary to per unit for phase currents excluding ArcI>.

CT = 750/5

I_{GN} = 525 A

Current injected to the relay's inputs is 7 A.

⇒ Per unit current is
I_{PU} = 7x750/(5x525) = 2.00 pu = 2.00 xI_{GN} = 200 %

Example 2: Secondary to per unit for ArcI>.

CT = 750/5

Current injected to the relay's inputs is 7 A.

⇒ Per unit current is
I_{PU} = 7/5 = 1.4 pu = 140 %

Example 3: Per unit to secondary for phase currents excluding ArcI>.

CT = 750/5

I_{GN} = 525 A

The relay setting is 2xI_{GN} = 2 pu = 200 %.

⇒ Secondary current is
I_{SEC} = 2x5x525/750 = 7 A

Example 4: Per unit to secondary for ArcI>.

CT = 750/5

The relay setting is 2 pu = 200 %.

⇒ Secondary current is
I_{SEC} = 2x5 = 10 A

Example 5: Secondary to per unit for residual current.

Input is I_{01} or I_{02}.

CT_0 = 50/1

Current injected to the relay's input is 30 mA.

⇒ Per unit current is
I_{PU} = 0.03/1 = 0.03 pu = 3 %

Example 6: Per unit to secondary for residual current.

Input is I_{01} or I_{02}.

CT_0 = 50/1

The relay setting is 0.03 pu = 3 %.

⇒ Secondary current is
I_{SEC} = 0.03x1 = 30 mA

Example 7: Secondary to per unit for residual current.

Input is I_{0Calc}.

CT = 750/5

Currents injected to the relay's I_{L1} input is 0.5 A.
I_{L2} = I_{L3} = 0.
⇒ Per unit current is
I_{PU} = 0.5/5 = 0.1 pu = 10 %

Example 8: Per unit to secondary for residual current.

Input is I_{0Calc}.

CT = 750/5

The relay setting is 0.1 pu = 10 %.

⇒ If I_{L2} = I_{L3} = 0, then secondary current to I_{L1} is
I_{SEC} = 0.1x5 = 0.5 A

7.10.2. Voltage scaling

Primary/secondary scaling of line-to-line voltages

	Line-to-line voltage scaling	
	Voltage measurement mode = "2LL+Uo"	Voltage measurement mode = "3LN"
secondary ⇒ primary	$U_{PRI} = U_{SEC} \cdot \frac{VT_{PRI}}{VT_{SEC}}$	$U_{PRI} = \sqrt{3} \cdot U_{SEC} \cdot \frac{VT_{PRI}}{VT_{SEC}}$
primary ⇒ secondary	$U_{SEC} = U_{PRI} \cdot \frac{VT_{SEC}}{VT_{PRI}}$	$U_{SEC} = \frac{U_{PRI}}{\sqrt{3}} \cdot \frac{VT_{SEC}}{VT_{PRI}}$

Example 1: Secondary to primary. Voltage measurement mode is "2LL+Uo".

VT = 12000/110

Voltage connected to the relay's input U_a or U_b is 100 V.
⇒ Primary voltage is U_{PRI} = 100x12000/110 = 10909 V

Example 2: Secondary to primary. Voltage measurement mode is "3LN".
VT = 12000/110

Three phase symmetric voltages connected to the relay's inputs Ua, Ub and Uc are 57.7 V.
⇒ Primary voltage is U_{PRI} = √3x58x12000/110 = 10902 V

Example 3: Primary to secondary. Voltage measurement mode is "2LL+Uo".

VT = 12000/110

The relay displays U_{PRI} = 10910 V.
⇒ Secondary voltage is U_{SEC} = 10910x110/12000 = 100 V

Example 4: Primary to secondary. Voltage measurement mode is "3LN".

VT = 12000/110

The relay displays $U_{12} = U_{23} = U_{31}$ = 10910 V.
⇒ Symmetric secondary voltages at Ua, U_b and U_c are
U_{SEC} = 10910/√3x110/12000 = 57.7 V.

Per unit [pu] scaling of line-to-line voltages

One per unit = 1 pu = 1xU_{GN} = 100 %, where U_{GN} = rated voltage of the generator.

	Line-to-line voltage scaling	
	Voltage measurement mode = "2LL+Uo"	Voltage measurement mode = "3LN"
secondary ⇒ per unit	$U_{PU} = \frac{U_{SEC}}{VT_{SEC}} \cdot \frac{VT_{PRI}}{U_{GN}}$	$U_{PU} = \sqrt{3} \cdot \frac{U_{SEC}}{VT_{SEC}} \cdot \frac{VT_{PRI}}{U_{GN}}$
per unit ⇒ secondary	$U_{SEC} = U_{PU} \cdot VT_{SEC} \cdot \frac{U_{GN}}{VT_{PRI}}$	$U_{SEC} = U_{PU} \cdot \frac{VT_{SEC}}{\sqrt{3}} \cdot \frac{U_{GN}}{VT_{PRI}}$

Example 1: Secondary to per unit. Voltage measurement mode is "2LL+Uo".

VT = 12000/110

U_{GN} = 11000 V

Voltage connected to the relay's input U_a or U_b is 100.8 V.
⇒ Per unit voltage is

U_{PU} = 100.8/110x12000/11000 = 1.00 pu = 1.00xU_{GN} = 100 %

Example 2: Secondary to per unit. Voltage measurement mode is "3LN".

VT = 12000/110

U_{GN} = 11000 V

Three symmetric phase-to-neutral voltages connected to the relay's inputs U_a,U_b and U_c are 58.2 V.
⇒ Per unit voltage is

U_{PU} = √3x58.2/110x12000/11000 = 1.00 pu = 1.00xU_{GN} = 100 %

Example 3: Per unit to secondary. Voltage measurement mode is "2LL+Uo".

VT = 12000/110

U_{GN} = 11000 V

The relay displays 1.00 pu = 100 %.
⇒ Secondary voltage is

U_{SEC} = 1.00x110x11000/12000 = 100.8 V

Example 4: Per unit to secondary. Voltage measurement mode is "3LN".

VT = 12000/110

U_{GN} = 11000 V

The relay displays 1.00 pu = 100 %.

⇒ Three symmetric phase-to-neutral voltages connected to the relay's inputs U_a,U_b and U_c are.

U_{SEC} = 1.00x110/√3x11000/12000 = 58.2 V

Per unit [pu] scaling of zero sequence voltage

	Zero-sequence voltage (U_0) scaling	
	Voltage measurement mode = "2LL+Uo", "1LL+Uo/LLy"	Voltage measurement mode = "3LN"
secondary ⇒ per unit	$U_{PU} = \frac{U_{SEC}}{U_{0SEC}}$	$U_{PU} = \frac{1}{VT_{SEC}} \cdot \frac{\left\| \overline{U}_a + \overline{U}_b + \overline{U}_c \right\|_{SEC}}{\sqrt{3}}$
per unit ⇒ secondary	$U_{SEC} = U_{PU} \cdot U_{0SEC}$	$\left\| \overline{U}_a + \overline{U}_b + \overline{U}_c \right\|_{SEC} = \sqrt{3} \cdot U_{PU} \cdot VT_{SEC}$

Example 1: Secondary to per unit. Voltage measurement mode is "2LL+U_0".
U_{0SEC} = 110 V (This is a configuration value corresponding to U_0 at full earth fault.)
Voltage connected to the device's input Uc is 22 V.
⇒ Per unit voltage is

U_{PU} = 22/110 = 0.20 pu = 20 %

Example 2: Secondary to per unit. Voltage measurement mode is "3LN".

VT = 12000/110

Voltage connected to the device's input U_a is 38.1 V, while $U_a = U_b = 0$.
⇒ Per unit voltage is

$U_{PU} = (\underline{38.1}+\underline{0}+\underline{0})/(\sqrt{3}\text{x}110)$ = 0.20 pu = 20 %

Example 3: Per unit to secondary. Voltage measurement mode is "2LL+Uo".
U_{0SEC} = 110 V (This is a configuration value corresponding to U_0 at full earth fault.)
The device displays U_0 = 20 %.
⇒ Secondary voltage at input Uc is

U_{SEC} = 0.20x110 = 22 V

Example 4: Per unit to secondary. Voltage measurement mode is "3LN".
VT = 12000/110
The device displays U_0 = 20 %.

⇒ If $U_b = U_c = 0$, then secondary voltages at U_a is
$U_{SEC} = \sqrt{3}$x0.2x110 = 38.1 V

8. Control functions

8.1. Output relays

The output relays are also called digital outputs. Any internal signal can be connected to the output relays using output matrix. An output relay can be configured as latched or non-latched. See output matrix for more details.

NOTE! If the device has the mA option, it is equipped with only three alarm relays from A1 to A3.

The difference between trip contacts and alarm contacts is the DC breaking capacity. See chapters 12.1.4 and 12.1.5 for details. The contacts are SPST normal open type (NO), except alarm relays A1, A2 and A3, which have change over contacts (SPDT).

Parameters of output relays

Parameter	Value	Unit	Description	Note
T1, T2	0 1		Status of trip output relay	F
A1 ... A5	0 1		Status of alarm output relay	F
IF	0 1		Status of the internal fault indication relay	F
Force	On Off		Force flag for output relay forcing for test purposes. This is a common flag for all output relays and protection stage status, too. Any forced relay(s) and this flag are automatically reset by a 5-minute timeout.	Set
REMOTE PULSES				
A1 ... A5	0.00 ... 99.98 or 99.99	s	Pulse length for direct output relay control via communications protocols. 99.99 s = Infinite. Release by writing "0" to the direct control parameter	Set
NAMES for OUTPUT RELAYS (editable with VAMPSET only)				
Description	String of max. 32 characters		Names for DO on VAMPSET screens. Default is "Trip relay n", n=1, 2 or "Alarm relay n", n=1...5	Set

Set = An editable parameter (password needed)

F = Editable when force flag is on

8.2. Digital inputs

There are 6 digital inputs available for control purposes. The polarity – normal open (NO) / normal closed (NC – and a delay can be configured according the application. The signals are available for the output matrix, block matrix, user's programmable logic etc.

The contacts connected to digital inputs DI1 ... DI6 must be dry (potential free). These inputs use the common internal 48 Vdc wetting voltage from terminal X3:1, only.

NOTE! These digital inputs must not be connected parallel with inputs of an another device.

Label and description texts can be edited with VAMPSET according the application. Labels are the short parameter names used on the local panel and descriptions are the longer names used by VAMPSET.

Parameters of digital inputs

Parameter	Value	Unit	Description	Set
DI1 ... DI6	0 1		Status of digital input	
DI COUNTERS				
DI1 ... DI6	0 ... 65535		Cumulative active edge counter	(Set)
DELAYS FOR DIGITAL INPUTS				
DI1 ... DI6	0.00 ... 60.00	s	Definite delay for both on and off transitions	Set
CONFIGURATION DI1 ... DI6				
Inverted	no yes		For normal open contacts (NO). Active edge is 0⇒1 For normal closed contacts (NC) Active edge is 1⇒0	Set
Alarm display	no yes		No pop-up display Alarm pop-up display is activated at active DI edge	Set
On event	On Off		Active edge event enabled Active edge event disabled	Set
Off event	On Off		Inactive edge event enabled Inactive edge event disabled	Set

Parameter	Value	Unit	Description	Set
NAMES for DIGITAL INPUTS (editable with VAMPSET only)				
Label	String of max. 10 characters		Short name for DIs on the local display Default is "DIn", n=1...6	Set
Description	String of max. 32 characters		Long name for DIs. Default is "Digital input n", n=1...6	Set

Set = An editable parameter (password needed)

8.3. Virtual inputs and outputs

There are four virtual inputs and six virtual outputs. The four virtual inputs acts like normal digital inputs. The state of the virtual input can be changed from display, communication bus and from VAMPSET. For example setting groups can be changed using virtual inputs.

Parameters of virtual inputs

Parameter	Value	Unit	Description	Set
VI1 ... VI4	0 1		Status of virtual input	
Events	On Off		Event enabling	Set
NAMES for VIRTUAL INPUTS (editable with VAMPSET only)				
Label	String of max. 10 characters		Short name for VIs on the local display Default is "VIn", n=1...4	Set
Description	String of max. 32 characters		Long name for VIs. Default is "Virtual input n", n=1...4	Set

Set = An editable parameter (password needed)

The six virtual outputs do act like output relays, but there are no physical contacts. Virtual outputs are shown in the output matrix and the block matrix. Virtual outputs can be used with the user's programmable logic and to change the active setting group etc.

8.4. Output matrix

By means of the output matrix, the output signals of the various protection stages, digital inputs, logic outputs and other internal signals can be connected to the output relays, front panel indicators, virtual outputs etc.

There are two LED indicators named "Alarm" and "Trip" on the front panel. Furthermore there are three general purpose LED indicators – "A", "B" and "C" – available for customer-specific indications. In addition, the triggering of the disturbance recorder (DR) and virtual outputs are configurable in the output matrix. See an example in Figure 8.4-1.

An output relay or indicator LED can be configured as latched or non-latched. A non-latched relay follows the controlling signal. A latched relay remains activated although the controlling signal releases.

There is a common "release latched" signal to release all the latched relays. This release signal resets all the latched output relays and indicators. The reset signal can be given via a digital input, via a keypad or through communication. Any digital input can be used for resetting. The selection of the input is done with the VAMPSET software under the menu "Release output matrix latches". Under the same menu, the "Release latches" parameter can be used for resetting.

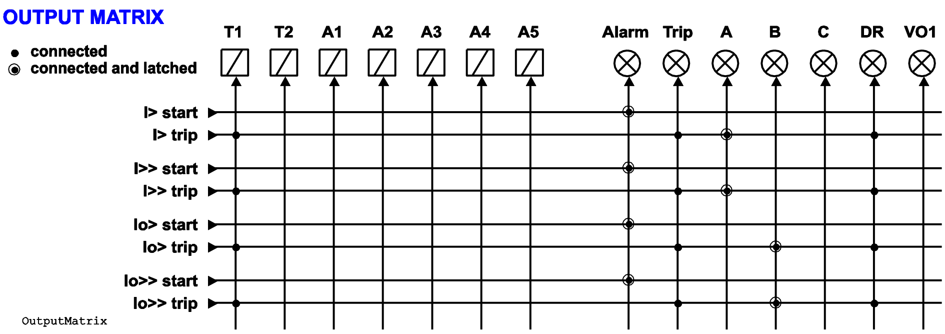


Figure 8.4-1 Output matrix.

8.5. Blocking matrix

By means of a blocking matrix, the operation of any protection stage can be blocked. The blocking signal can originate from the digital inputs DI1 to DI6, or it can be a start or trip signal from a protection stage or an output signal from the user's programmable logic. In the block matrix Figure 8.5-1 an active blocking is indicated with a black dot (•) in the crossing point of a blocking signal and the signal to be blocked.

NOTE! The display show 20 DIs, even only 6 of them are available. Digital input 19 & 20 are only available with DI19, DI20 option.

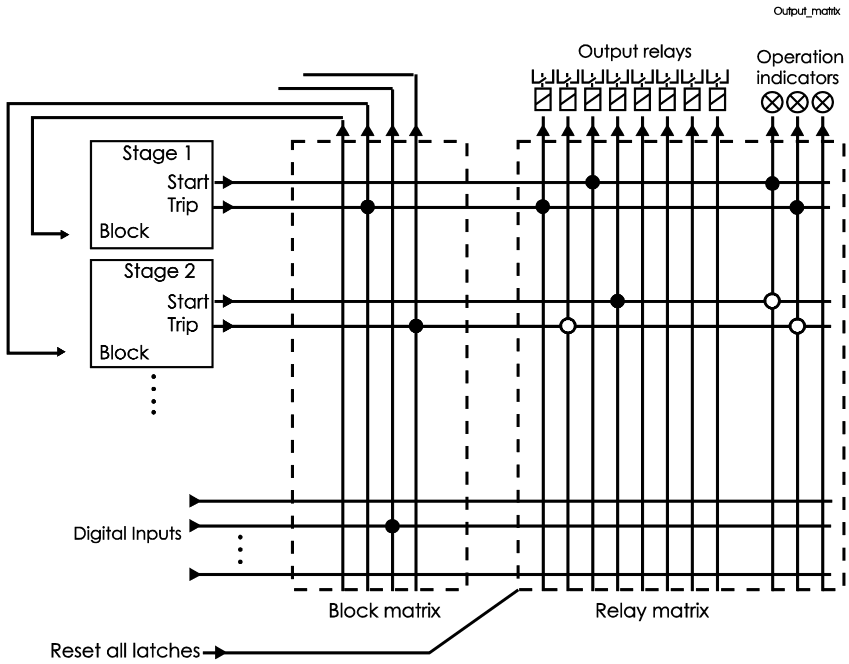


Figure 8.5-1 Blocking matrix and output matrix

8.6. Controllable objects

The relay allows controlling of six objects, that is, circuit-breakers, disconnectors and earthing switches. Controlling can be done by "select-execute" or "direct control" principle.

The logic functions can be used to configure interlocking for a safe controlling before the output pulse is issued. The objects 1...6 are controllable while the objects 7...8 are only able to show the status.

Controlling is possible by the following ways:

- through the local HMI
- through a remote communication
- through a digital input.

The connection of an object to specific output relays is done via an output matrix (object 1-6 open output, object 1-65 close output). There is also an output signal “Object failed”, which is activated if the control of an object fails.

Object states

Each object has the following states:

Setting	Value	Description
Object state	Undefined (00)	Actual state of the object
	Open	
	Close	
	Undefined (11)	

Basic settings for controllable objects

Each controllable object has the following settings:

Setting	Value	Description
DI for ‘obj open’	None, any digital input, virtual input or virtual output	Open information
DI for ‘obj close’		Close information
DI for ‘obj ready’		Ready information
Max ctrl pulse length	0.02 … 600 s	Pulse length for open and close commands
Completion timeout	0.02 … 600 s	Timeout of ready indication
Object control	Open/Close	Direct object control

If changing states takes longer than the time defined by “Max ctrl pulse length” setting, object fails and “Object failure” matrix signal is set. Also undefined-event is generated. “Completion timeout” is only used for the ready indication. If “DI for ‘obj ready’” is not set, completion timeout has no meaning.

Output signals of controllable objects

Each controllable object has 2 control signals in matrix:

Output signal	Description
Object x Open	Open control signal for the object
Object x Close	Close control signal for the object

These signals send control pulse when an object is controlled by digital input, remote bus, auto-reclose etc.

Settings for read-only objects

Each read-only object has the following settings:

Setting	Value	Description
DI for 'obj open'	None, any digital input, virtual input or virtual output	Open information
DI for 'obj close'		Close information
Object timeout	0.02 … 600 s	Timeout for state changes

If changing states takes longer than the time defined by "Object timeout" setting, object fails and "Object failure" matrix signal is set. Also undefined-event is generated.

Controlling with DI (firmware version >= 5.53)

Objects can be controlled with digital input, virtual input or virtual output. There are four settings for each controllable object:

Setting	Active
DI for remote open control	In remote state
DI for remote close control	
DI for local open control	In local state
DI for local close control	

If the device is in local control state, the remote control inputs are ignored and vice versa. Object is controlled when a rising edge is detected from the selected input. Length of digital input pulse should be at least 60 ms.

8.6.1. Local/Remote selection

In Local mode, the output relays can be controlled via a local HMI, but they cannot be controlled via a remote serial communication interface.

In Remote mode, the output relays cannot be controlled via a local HMI, but they can be controlled via a remote serial communication interface.

The selection of the Local/Remote mode is done by using a local HMI, or via one selectable digital input. The digital input is normally used to change a whole station to a local or remote mode. The selection of the L/R digital input is done in the “Objects” menu of the VAMPSET software.

NOTE! A password is not required for a remote control operation.

8.7. Logic functions

The relay supports customer-defined programmable logic for boolean signals. The logic is designed by using the VAMPSET setting tool and downloaded to the relay. Functions available are:

- AND
- OR
- XOR
- NOT
- COUNTERs
- RS & D flip-flops

Maximum number of outputs is 20. Maximum number of input gates is 31. An input gate can include any number of inputs.

For detailed information, please refer to the VAMPSET manual (VVAMPSET/EN M/xxxx).

9. Communication

9.1. Communication ports

The relay has three communication ports as standard. A fourth port, Ethernet, is available as option. See Figure 9.1-1.

There are three communication ports in the rear panel. The Ethernet port is optional. The X4 connector includes two ports: local port and extension port. The front panel RS-232 port will shut off the local port on the rear panel when a VX003 cable is inserted.

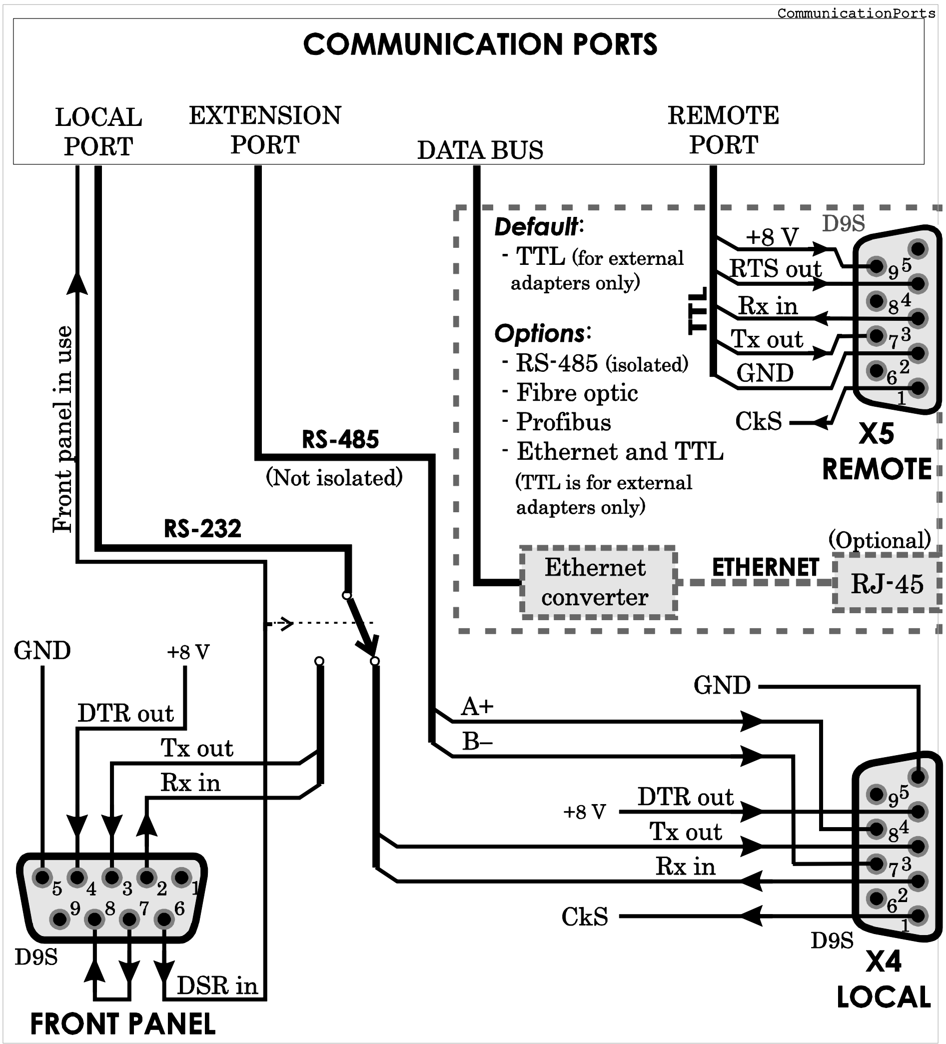


Figure 9.1-1 Communication ports and connectors. By default the X5 is a D9S type connector with TTL interface. The DSR signal from the front panel port selects the active connector for the RS232 local port.

By default the remote port has a TTL interface. It can only be used together with external converters or converting cables. Inbuilt options for RS-485, fibre optic (plastic/plastic, plastic/glass, glass/plastic or glass/glass), Profibus and Ethernet are available.

9.1.1. Local port X4

The local port has two connectors:

- On the front panel
- X4 the rear panel (D9S pins 2, 3 and 5)

Only one can be used at a time.

NOTE! The extension port is locating in the same X4 connector.

NOTE! When the VX003 cable is inserted to the front panel connector it activates the front panel port and disables the rear panel local port by connecting the DTR pin 6 and DSR pin 4 together. See Figure 9.1-1.

Protocol for the local port

The front panel port is always using the command line protocol for VAMPSET regardless of the selected protocol for the rear panel local port.

If other than "None" protocol is selected for the rear panel local port, the front panel connector, when activated, is still using the plain command line interface with the original speed, parity etc. For example if the rear panel local port is used for remote VAMPSET communication using SPA-bus default 9600/7E1, it is possible to temporarily connect a PC with VAMPSET to the front panel connector with the default 38400/8N1. While the front panel connector is in use, the rear panel local port is disabled. The communication parameter display on the local display will show the active parameter values for the local port.

Physical interface

The physical interface of this port is RS-232.

Parameters

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for the rear panel local port.	Set
	None		Command line interface for VAMPSET	
	SpaBus		SPA-bus (slave)	
	ProfibusDP		Profibus DB (slave)	
	ModbusSla		Modbus RTU slave	
	ModbusTCPs		Modbus TCP slave	
	IEC-103		IEC-60870-5-103 (slave)	
	ExternalIO		Modbus RTU master for external I/O-modules	
	DNP3		DNP 3.0	
Msg#	0 ... 2^{32}–1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 ... 2^{16}–1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 ... 2^{16}–1		Timeout errors since the device has restarted or since last clearing	Clr
	speed/DPS Default = 38400/8N1 for VAMPSET		Display of actual communication parameters. speed = bit/s D = number of data bits P = parity: none, even, odd S = number of stop bits	1)
VAMPSET communication (Direct or SPA-bus embedded command line interface)				
Tx	bytes/size		Unsent bytes in transmitter buffer/size of the buffer	
Msg#	0 ... 2^{32}–1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 ... 2^{16}–1		Errors since the device has restarted or since last clearing	Clr
Tout	0 ... 2^{16}–1		Timeout errors since the device has restarted or since last clearing	Clr

Set = An editable parameter (password needed)

Clr = Clearing to zero is possible

1) The communication parameters are set in the protocol specific menus. For the local port command line interface the parameters are set in configuration menu.

9.1.2. Remote port X5

Physical interface

The physical interface of this port depends of the communication letter in the order code. See Figure 9.1-1, chapter 11 and the table below. The TTL interface is for external converters and converter cables only. It is not suitable for direct connection to distances more than one meter.

Parameters

Parameter	Value	Unit	Description	Note
Protocol	 None SPA-bus ProfibusDP ModbusSla ModbusTCPs IEC-103 ExternalIO DNP3		Protocol selection for remote port - SPA-bus (slave) Profibus DB (slave) Modbus RTU slave Modbus TCP slave IEC-60870-5-103 (slave) Modbus RTU master for external I/O-modules DNP 3.0	Set
Msg#	0 ... 2^{32}–1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 ... 2^{16}–1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 ... 2^{16}–1		Timeout errors since the device has restarted or since last clearing	Clr
	speed/DPS		Display of current communication parameters. speed = bit/s D = number of data bits P = parity: none, even, odd S = number of stop bits	1)
Debug	 No Binary ASCII		Echo to local port No echo For binary protocols For SPA-bus protocol	Set

Set = An editable parameter (password needed)

Clr = Clearing to zero is possible

1) The communication parameters are set in the protocol specific menus. For the local port command line interface the parameters are set in configuration menu.

9.1.3. Extension port X4

This is a non-isolated RS-485 port for external I/O devices. The port is located in the same rear panel D9S connector X4 as the local port, but pins (7, 8, 5) are used instead of the standard RS-232 pins (2, 3, 5) used by the local port. See Figure 9.1-1.

Parameters

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for the extension port.	Set
	None		Command line interface for VAMPSET	
	SPA-bus		SPA-bus (slave)	
	ProfibusDP		Profibus DB (slave)	
	ModbusSla		Modbus RTU slave	
	ModbusTCPs		Modbus TCP slave	
	IEC-103		IEC-60870-5-103 (slave)	
	ExternalIO		Modbus RTU master for external I/O-modules	
	DNP3		DNP 3.0	
Msg#	0 ... 2^{32}–1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 ... 2^{16}–1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 ... 2^{16}–1		Timeout errors since the device has restarted or since last clearing	Clr
	speed/DPS Default = 38400/8N1 for VAMPSET		Display of actual communication parameters. speed = bit/s D = number of data bits P = parity: none, even, odd S = number of stop bits	1)

Set = An editable parameter (password needed)

Clr = Clearing to zero is possible

1) The communication parameters are set in the protocol specific menus. For the local port command line interface the parameters are set in configuration menu.

9.1.4. Ethernet port

IEC61850 and Modbus TCP use ethernet communication. Also VAMPSET, SPA-bus and DNP 3.0 communication can be directed via TCP/IP.

Parameters

Parameter	Value	Unit	Description	Set
Protoc	 None ModbusTCPs IEC 61850 Ethernet/IP		Protocol selection for the extension port. Command line interface for VAMPSET Modbus TCP slave IEC-61850 protocol Ethernet/IP protocol	Set
Port	nnn		Ip port for protocol, default 102	Set
IpAddr	n.n.n.n		Internet protocol address (set with VAMPSET)	Set
NetMsk	n.n.n.n		Net mask (set with VAMPSET)	Set
Gatew	default = 0.0.0.0		Gateway IP address (set with VAMPSET)	Set
NTPSvr	n.n.n.n		Network time protocol server (set with VAMPSET) 0.0.0.0 = no SNTP	Set
VS Port	nn		IP port for Vampset	Set
KeepAlive	nn		TCP keepalive interval	Set
MAC	nnnnnnnnnnnn		MAC address	
Msg#	nnn		Message counter	
Errors	nnn		Error counter	
Tout	nnn		Timeout counter	

Set = An editable parameter (password needed)

9.2. Communication protocols

This protocols enable the transfer of the following type of data:

- events
- status information
- measurements
- control commands.
- clock synchronizing
- Settings (SPA-bus and embedded SPA-bus only)

9.2.1. PC communication

PC communication is using a VAMP specified command line interface. The VAMPSET program can communicate using the local RS-232 port or using ethernet interface. It is also possible to select SPA-bus protocol for the local port and configure the VAMPSET to embed the command line interface inside SPA-bus messages. For ethernet interface configuration see chapter 9.1.4.

9.2.2. Modbus TCP and Modbus RTU

These Modbus protocols are often used in power plants and in industrial applications. The difference between these two protocols is the media. Modbus TCP uses Ethernet and Modbus RTU uses asynchronous communication (RS-485, optic fibre, RS-232).

VAMPSET will show the list of all available data items for Modbus. A separate document “Modbus parameters.pdf” is also available.

The Modbus communication is activated usually for remote port via a menu selection with parameter "Protocol". See chapter 9.1.

For ethernet interface configuration see chapter 9.1.4.

Parameters

Parameter	Value	Unit	Description	Note
Addr	1 – 247		Modbus address for the device. Broadcast address 0 can be used for clock synchronizing. Modbus TCP uses also the TCP port settings.	Set
bit/s	1200 2400 4800 9600 19200	bps	Communication speed for Modbus RTU	Set
Parity	None Even Odd		Parity for Modbus RTU	Set

Set = An editable parameter (password needed)

9.2.3. Profibus DP

The Profibus DP protocol is widely used in industry. An external VPA 3CG or an internal Profibus module (see the order code in chapter 15.) is required.

Device profile "continuous mode"

In this mode the device is sending a configured set of data parameters continuously to the Profibus DP master. The benefit of this mode is the speed and easy access to the data in the Profibus master. The drawback is the maximum buffer size of 128 bytes, which limits the number of data items transferred to the master. Some PLCs have their own limitation for the Profibus buffer size, which may further limit the number of transferred data items.

Device profile "Request mode"

Using the request mode it is possible to read all the available data from the VAMP device and still use only a very short buffer for Profibus data transfer. The drawback is the slower overall speed of the data transfer and the need of increased data processing at the Profibus master as every data item must be separately requested by the master.

NOTE! In request more it is not possible to read continuously only one single data item. At least two data items must be read in turn to get updated data from the device.

There is a separate manual for VPA 3CG available for the continuous mode and request mode.

Available data

VAMPSET will show the list of all available data items for both modes. A separate document “Profibus parameters.pdf” is also available.

The Profibus DP communication is activated usually for remote port via a menu selection with parameter "Protocol". See chapter 9.1.

Parameters

Parameter	Value	Unit	Description	Note
Mode	 Cont Reqst		Profile selection Continuous mode Request mode	Set
bit/s	2400	bps	Communication speed from the main CPU to the Profibus converter. (The actual Profibus bit rate is automatically set by the Profibus master and can be up to 12 Mbit/s.)	
Emode	 Channel (Limit60) (NoLimit)		Event numbering style. Use this for new installations. (The other modes are for compatibility with old systems.)	(Set)
InBuf		bytes	Size of Profibus master's Rx buffer. (data to the master)	1) 3)
OutBuf		bytes	Size of Profibus master's Tx buffer. (data from the master)	2) 3)
Addr	1 – 247		This address has to be unique within the Profibus network system.	Set
Conv	 – VE		Converter type No converter recognized Converter type "VE" is recognized	4)

Set = An editable parameter (password needed)

Clr = Clearing to zero is possible

1) In continuous mode the size depends of the biggest configured data offset of a data item to be send to the master. In request mode the size is 8 bytes.

2) In continuous mode the size depends of the biggest configured data offset of a data to be read from the master. In request mode the size is 8 bytes.

3) When configuring the Profibus master system, the length of these buffers are needed. The device calculates the lengths according the Profibus data and profile configuration and the values define the in/out module to be configured for the Profibus master.

4) If the value is "□", Profibus protocol has not been selected or the device has not restarted after protocol change or there is a communication problem between the main CPU and the Profibus ASIC.

9.2.4. SPA-bus

The manager has full support for the SPA-bus protocol including reading and writing the setting values. Also reading of multiple consecutive status data bits, measurement values or setting values with one message is supported.

Several simultaneous instances of this protocol, using different physical ports, are possible, but the events can be read by one single instance only.

There is a separate document “Spabus parameters.pdf” of SPA-bus data items available.

Parameters

Parameter	Value	Unit	Description	Note
Addr	1 – 899		SPA-bus address. Must be unique in the system.	Set
bit/s	1200 2400 4800 9600 (default) 19200	bps	Communication speed	Set
Emode	Channel (Limit60) (NoLimit)		Event numbering style. Use this for new installations. (The other modes are for compatibility with old systems.)	(Set)

Set = An editable parameter (password needed)

9.2.5. IEC 60870-5-101

The IEC 60870-5-101 standard is derived from the IEC 60870-5 protocol standard definition. In Vamp devices, IEC 60870-5-101 communication protocol is available via menu selection. The Vamp unit works as a controlled outstation (slave) unit in unbalanced mode.

Supported application functions include process data transmission, event transmission, command transmission, general interrogation, clock synchronization, transmission of integrated totals, and acquisition of transmission delay.

For more information on IEC 60870-5-101 in Vamp devices refer to the “IEC 101 Profile checklist & datalist” document.

Parameters

Parameter	Value	Unit	Description	Note
bit/s	1200 2400 4800 9600	bps	Bitrate used for serial communication.	Set
Parity	None Even Odd		Parity used for serial communication	Set
LLAddr	1 - 65534		Link layer address	Set
LLAddrSize	1 – 2	bytes	Size of Link layer address	Set
ALAddr	1 – 65534		ASDU address	Set
ALAddrSize	1 – 2	Bytes	Size of ASDU address	Set
IOAddrSize	2 - 3	Bytes	Information object address size. (3-octet addresses are created from 2-octet addresses by adding MSB with value 0.)	Set
COTsize	1	Bytes	Cause of transmission size	
TTFormat	Short Full		The parameter determines time tag format: 3-octet time tag or 7-octet time tag.	Set
MeasFormat	Scaled Normalized		The parameter determines measurement data format: normalized value or scaled value.	Set
DbandEna	No Yes		Dead-band calculation enable flag	Set
DbandCy	100 - 10000	ms	Dead-band calculation interval	Set

Set = An editable parameter (password needed)

9.2.6. IEC 60870-5-103

The IEC standard 60870-5-103 "*Companion standard for the informative interface of protection equipment*" provides standardized communication interface to a primary system (master system).

The unbalanced transmission mode of the protocol is used, and the device functions as a secondary station (slave) in the communication. Data is transferred to the primary system using "data acquisition by polling"-principle. The IEC functionality includes the following application functions:

- station initialization
- general interrogation
- clock synchronization and
- command transmission.

It is not possible to transfer parameter data or disturbance recordings via the IEC 103 protocol interface.

The following ASDU (Application Service Data Unit) types will be used in communication from the device:

- ASDU 1: time tagged message
- ASDU 3: Measurands I
- ASDU 5: Identification message
- ASDU 6: Time synchronization and
- ASDU 8: Termination of general interrogation.

The device will accept:

- ASDU 6: Time synchronization
- ASDU 7: Initiation of general interrogation and
- ASDU 20: General command.

The data in a message frame is identified by:

- type identification
- function type and
- information number.

These are fixed for data items in the compatible range of the protocol, for example, the trip of I> function is identified by: type identification = 1, function type = 160 and information number = 90. "Private range" function types are used for such data items, which are not defined by the standard (e.g. the status of the digital inputs and the control of the objects).

The function type and information number used in private range messages is configurable. This enables flexible interfacing to different master systems.

For more information on IEC 60870-5-103 in Vamp devices refer to the “IEC103 Interoperability List” document.

Parameters

Parameter	Value	Unit	Description	Note
Addr	1 – 254		An unique address within the system	Set
bit/s	9600 19200	bps	Communication speed	Set
MeasInt	200 – 10000	ms	Minimum measurement response interval	Set
SyncRe	Sync Sync+Proc Msg Msg+Proc		ASDU6 response time mode	Set

Set = An editable parameter (password needed)

Parameters for disturbance record reading

Parameter	Value	Unit	Description	Note
ASDU23	On Off		Enable record info message	Set
Smpls/msg	1–25		Record samples in one message	Set
Timeout	10–10000	s	Record reading timeout	Set
Fault			Fault identifier number for IEC-103. Starts + trips of all stages.	
TagPos			Position of read pointer	
Chn			Active channel	
ChnPos			Channel read position	
Fault numbering				
Faults			Total number of faults	
GridFlts			Fault burst identifier number	
Grid			Time window to classify faults together to the same burst.	Set

Set = An editable parameter (password needed)

9.2.7. DNP 3.0

The relay supports communication using DNP 3.0 protocol.

The following DNP 3.0 data types are supported:

- binary input
- binary input change
- double-bit input
- binary output
- analog input
- counters

Additional information can be obtained from the “DNP 3.0 Device Profile Document” for VAMP 2xx.

DNP 3.0 communication is activated via menu selection. RS-485 interface is often used but also RS-232 and fibre optic interfaces are possible.

Parameters

Parameter	Value	Unit	Description	Set
bit/s	4800 9600 (default) 19200 38400	bps	Communication speed	Set
Parity	None (default) Even Odd		Parity	Set
SlvAddr	1 – 65519		An unique address for the device within the system	Set
MstrAddr	1 – 65519 255=default		Address of master	Set
LLTout	0 – 65535	ms	Link layer confirmation timeout	Set
LLRetry	1 – 255 1=default		Link layer retry count	Set
APLTout	0 – 65535 5000=default	ms	Application layer confirmation timeout	Set
CnfMode	EvOnly (default) All		Application layer confirmation mode	Set
DBISup	No (default) Yes		Double-bit input support	Set
SyncMode	0 – 65535	s	Clock synchronization request interval. 0 = only at boot	Set

Set = An editable parameter (password needed)

9.2.8. External I/O (Modbus RTU master)

External Modbus I/O devices can be connected to the relay using this protocol. (See chapter 11.7.2 External input / output module for more information).

9.2.9. IEC 61850

The relay supports communication using IEC 61850 protocol with native implementation. IEC 61850 protocol is available with the optional inbuilt Ethernet port. The protocol can be used to read / write static data from the relay or to receive events and to receive / send GOOSE messages to other relays.

IEC 61850 serve interface is capable of:

- Configurable data model: selection of logical nodes corresponding to active application functions
- Configurable pre-defined data sets
- Supported dynamic data sets created by clients
- Supported reporting function with buffered and unbuffered Report Control Blocks
- Supported control model: direct with normal security
- Supported horizontal communication with GOOSE: configurable GOOSE publisher data sets, configurable filters for GOOSE subscriber inputs, GOOSE inputs available in the application logic matrix

Additional information can be obtained from the separate documents “IEC 61850 conformance statement.pdf”, “IEC 61850 Protocol data.pdf” and “Configuration of IEC 61850 interface.pdf” on our website.

IEC 61850 main config parameters

Parameter	Value	Unit	Description	Set
Port	0 - 64000		IP protocol port	Set
Check upper addresses	Yes / No		If the checkbox 'Check upper addresses' is checked the below parameters are also checked and used for addressing when the client is communicating to the device, by default this is disabled.	Set
.			The below parameters are ACSE association parameters described in the standard part 61850-8-1	
AP ID	nnn.nnn.nnn.nnn		ACSE AP title value	Set
AE Qualifier	0 – 64000		ACSE AE qualifier	
P Selector	0 – 4200000000		Presentation selector	
S Selector	0 – 64000		Session selector	
T Selector	0 – 64000		Transport selector	
IED Name	String		Identifcation of the device. Each device must have unique name.	
Delete dynamic datasets	command		Send command to clear all dynamic datasets	

9.2.10. EtherNet/IP

The relay supports communication using EtherNet/IP protocol which is a part of CIP (Common Industrial Protocol) family. EtherNet/IP protocol is available with the optional inbuilt Ethernet port. The protocol can be used to read / write data from the relay using request / response communication or via cyclic messages transporting data assigned to assemblies (sets of data).

EtherNet/IP main features:

- Static data model: 2 standard objects (Overload and Control Supervisor), 2 private objects (one for digital data and one for analog data) and 4 configuration objects for protection functions configuration
- Two configurable assemblies (one producing and one consuming) with the maximum capacity of 128 bytes each EDS file that can be fed to any client supporting EDS files: can be generated at any time, all changes to EtherNet/IP configuration (see configuration parameters in table below) or to assemblies' content require generating of the new EDS file.
- Three types of communications are supported: UCMM (one time request / response), Class 3 connection (cyclic request / response) and Class 1 connection (cyclic IO messages containing assemblies' data)

EtherNet/IP implementation on VAMP relay serves as a server and is not capable of initiating communication

EtherNet/IP main configuration parameters:

Parameter	Range	Description
IP address		IP protocol address identifing device in the network
Multicast IP		Multicast IP address used for sending IO messages
Multicast TTL	1-100	Time to live of the IO messages sent to multicast address
Vendor ID	1-65535	Identification of a vendor by number
Device Type	0-65535	Indication of general type of product
Product Code	1-65535	Identification of a particular product of an individual vendor
Major Revision	1-127	Major revision of the item the Identity Object represents
Minor Revision	1-255	Minor revision of the item the Identity Object represents
Serial Number	0-4294967295	Serial number of device
Product Name	32 chars	Human readable identification
Producing Instance	1-1278	Instance number of producing assembly
Include Run/Idle Header (Producing)	On/Off	Include or exlude Run/Idle Header in an outgoing IO messages
Consuming Instance	1-1278	Instance number of consuming assembly
Include Run/Idle Header (Consuming)	On/Off	Expect presence or absence of Run/Idle Header in an incoming IO messages

10. Applications

The device comprises all the essential protection functions needed for a generator, except the differential protection function.

Thanks to the comprehensive range of protection functions the generator protection relay can be used as the main protection for a variety of generators from small diesel power plants to large hydro power plants in the power range from 1 to 100 MW.

Especially versatile and flexible protection functions are provided for the generator earth-fault protection. These features are needed, when for instance, several generators are connected in parallel to the same busbar but their earthing principles differ.

The other energizing connections, except for the ones for the earth-fault protection, are independent of the generator size and type. For large generator a higher accuracy of the protection functions is needed. Being based on numerical signal processing and high-resolution A/D conversion the device fulfils also these requirements.

The three generator protection applications on the following pages illustrate how the flexibility of the device can be utilized.

10.1. Directly connected generator

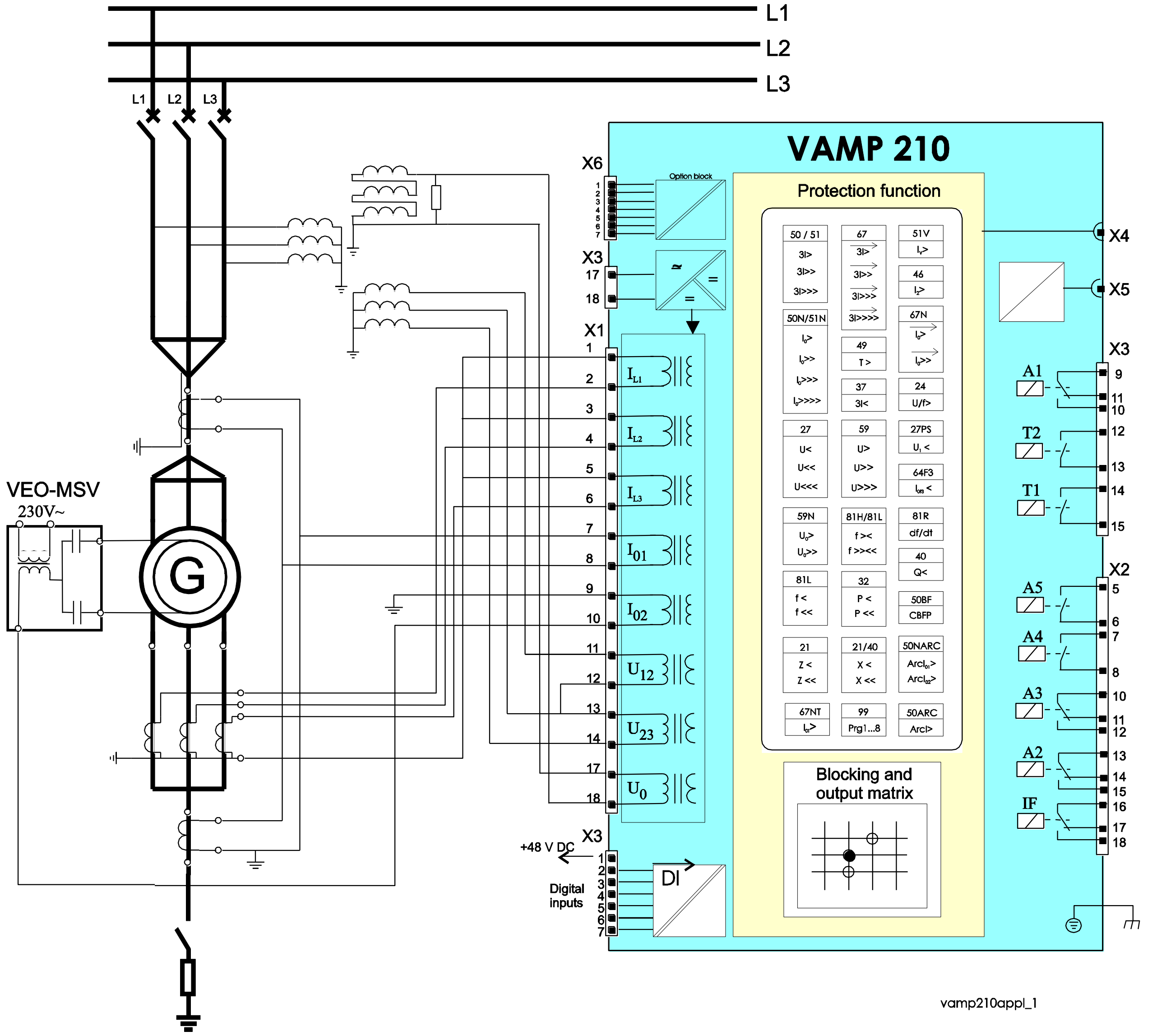


Figure 10.1-1 Generator connected directly to the distribution busbar. Earthed generator neutral.

The device is suitable for use in directly earthed, high/low resistance earthed and isolated systems. The differential and directional earth-fault protection provides a sensitive and selective protection solution in high resistance earthed and isolated systems.

In directly earthed or low resistance earthed systems the non-directional earth-fault stage constitutes a sufficiently selective earth-fault protection when energized from two current transformers forming a differential current connection.

The rotor earth-fault protection can be realized with the non-directional earth-fault stage using the energizing current input I_{02} in combination with a simple current injection device, for example type VEO-MSV.

10.2. Directly connected generator with unearthed generator neutral

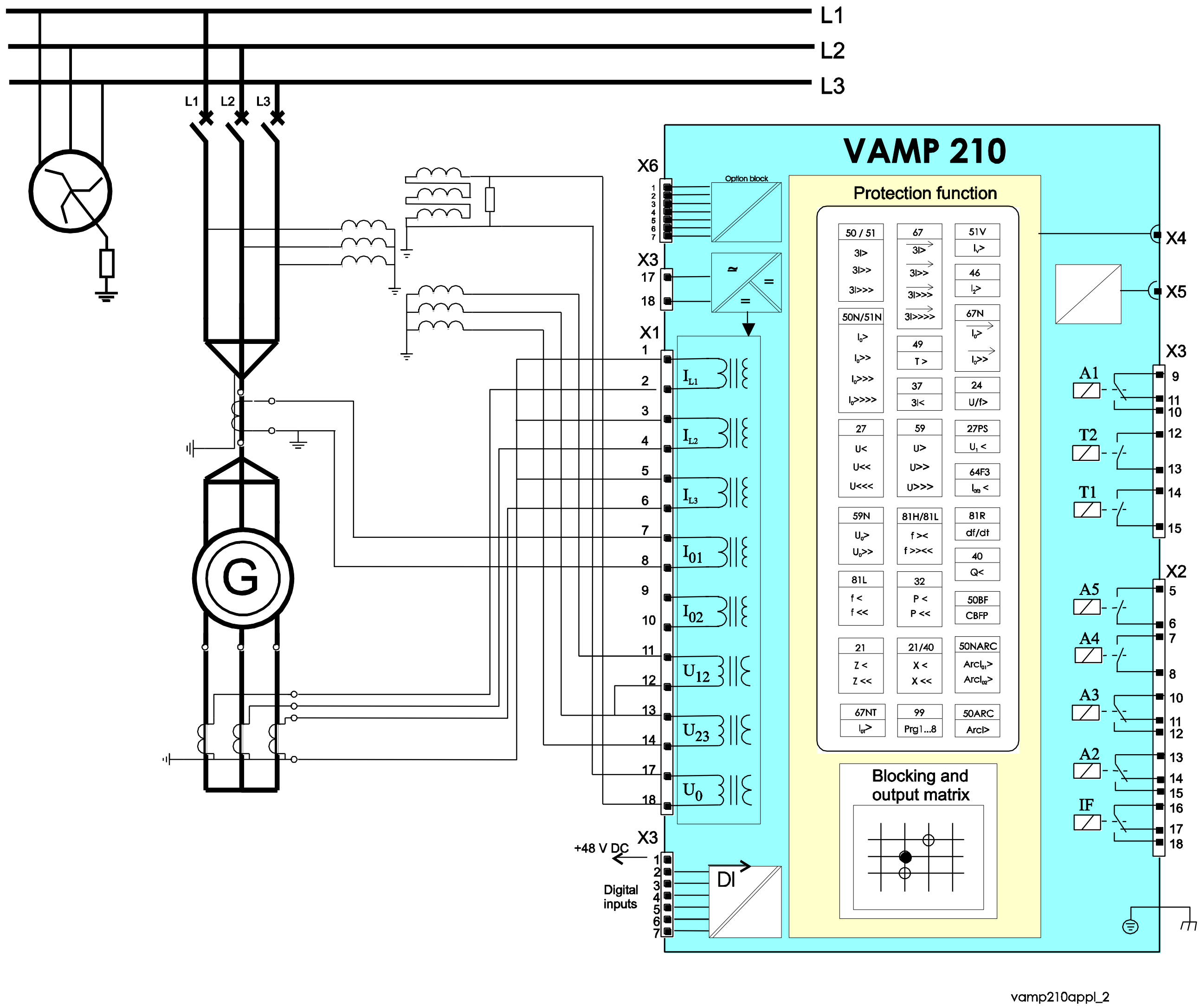


Figure 10.2-1 Generator connected directly to the distribution busbar. Unearthed generator neutral.

The neutral point of the generator winding is unearthed. The busbar system is earthed via a separate earthing transformer. In this case the earth-fault protection principle is straight-forward. It is simply based on the measurement of the earth-fault current (I_{01}) between the generator and the distribution busbar.

10.3. Generator-transformer unit

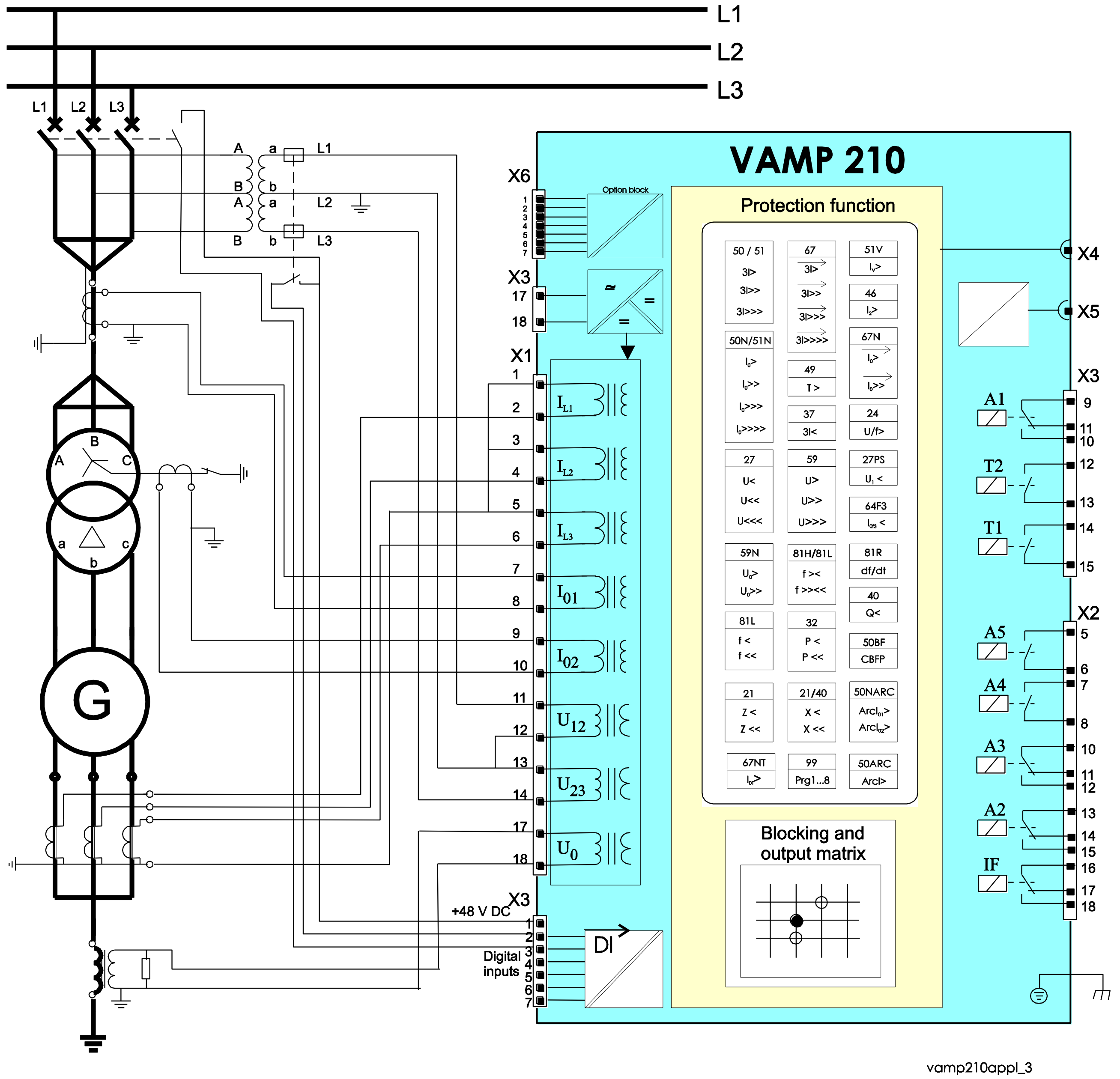


Figure 10.3-1 Generator-transformer unit

Besides the typical generator protection functions the device includes the transformer earth-fault protection. Whatever phase difference and voltage ratio of the transformer can be compensated in the relay in case VTs and CTs are on different sides of the unit transformer.

The earth-fault protection of the transformer is based on an OR-function between the current inputs I_{01} and I_{02}.

The stator earth-fault protection (reach 95%) is based on measuring the fundamental frequency component of the zero sequence voltage U_0 with the overvoltage stage (59GN).

Via the digital inputs of the relay various signals can be transferred into the relay, such as information about the operation of a MCB in the measuring circuit or circuit-breaker status information.

10.4. Trip circuit supervision

Trip circuit supervision is used to ensure that the wiring from the protective device to a circuit-breaker is in order. This circuit is unused most of the time, but when a protection device detects a fault in the network, it is too late to notice that the circuit-breaker cannot be tripped because of a broken trip circuitry.

The digital inputs of the device can be used for trip circuit monitoring. The dry digital inputs are most suitable for trip circuit supervision. The first six digital inputs of VAMP 200 series relays are not dry and an auxiliary miniature relay is needed, if these inputs are used for trip circuit supervision.

Also the closing circuit can be supervised, using the same principle.

In many applications the optimum digital inputs for trip circuit supervision are the optional inputs DI19 and DI20. They don't share their terminals with any other digital inputs.

10.4.1. Trip circuit supervision with one digital input

The benefits of this scheme is that only one digital inputs is needed and no extra wiring from the relay to the circuit breaker (CB) is needed. Also supervising a 24 Vdc trip circuit is possible.

The drawback is that an external resistor is needed to supervise the trip circuit on both CB positions. If supervising during the closed position only is enough, the resistor is not needed.

- The digital input is connected parallel with the trip contacts (Figure 10.4.1-1).
- The digital input is configured as Normal Closed (NC).
- The digital input delay is configured longer than maximum fault time to inhibit any superfluous trip circuit fault alarm when the trip contact is closed.
- The digital input is connected to a relay in the output matrix giving out any trip circuit alarm.
- The trip relay should be configured as non-latched. Otherwise, a superfluous trip circuit fault alarm will follow after the trip contact operates, and the relay remains closed because of latching.
- By utilizing an auxiliary contact of the CB for the external resistor, also the auxiliary contact in the trip circuit can be supervised.
- When using the dry digital inputs DI7..., using the other inputs of the same group, sharing a common terminal, is limited.
- When using the wet digital inputs DI1 ... DI6, an auxiliary relay is needed.

Using optional DI19, DI20

Note: In the device only the optional digital inputs DI19 and DI20 are dry (see the ordering code for this option).

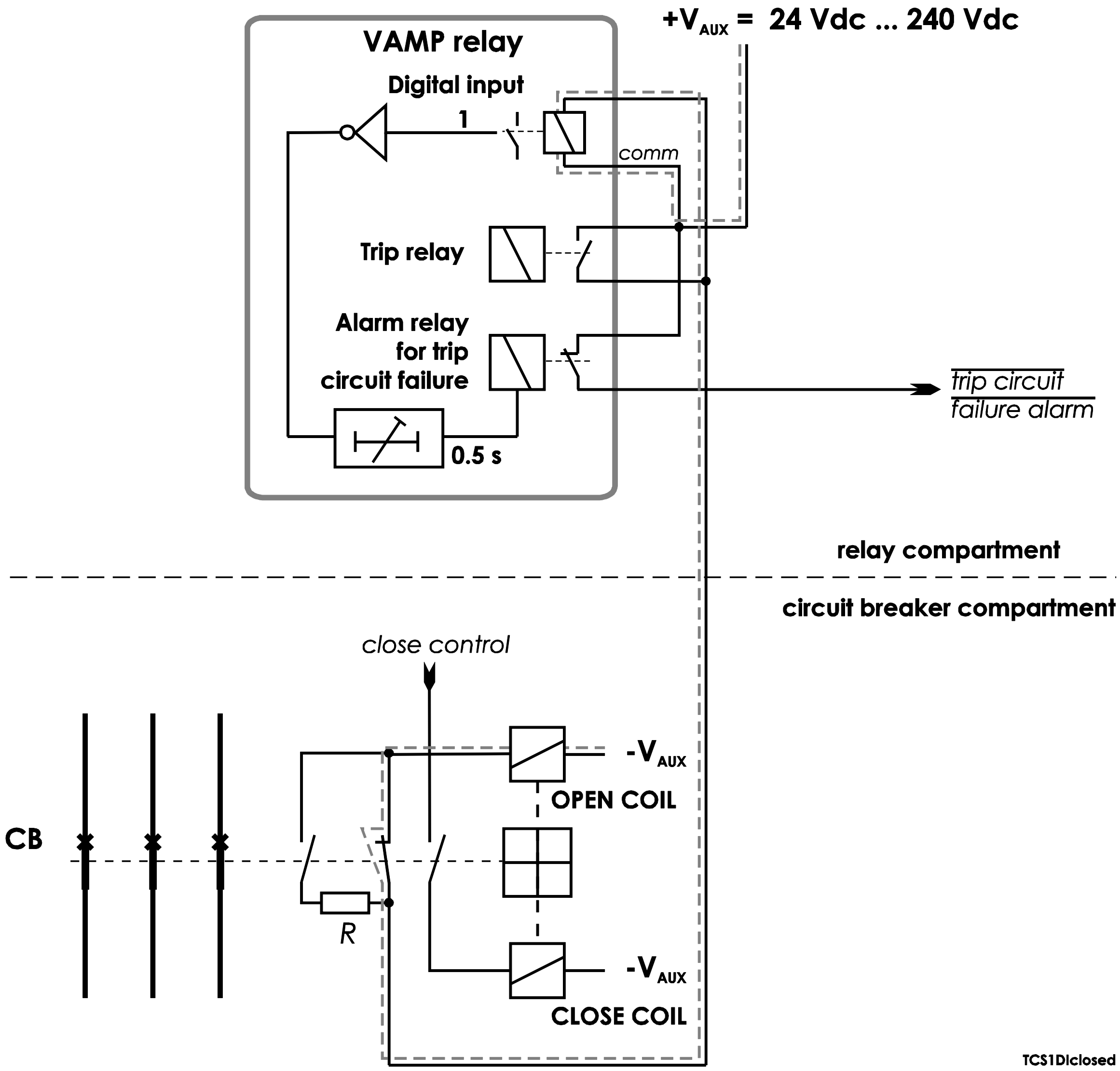


Figure 10.4.1-1 Trip circuit supervision using a single dry digital input and an external resistor R. The circuit-breaker is in the closed position. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete. This is applicable for dry inputs DI7...DI20.

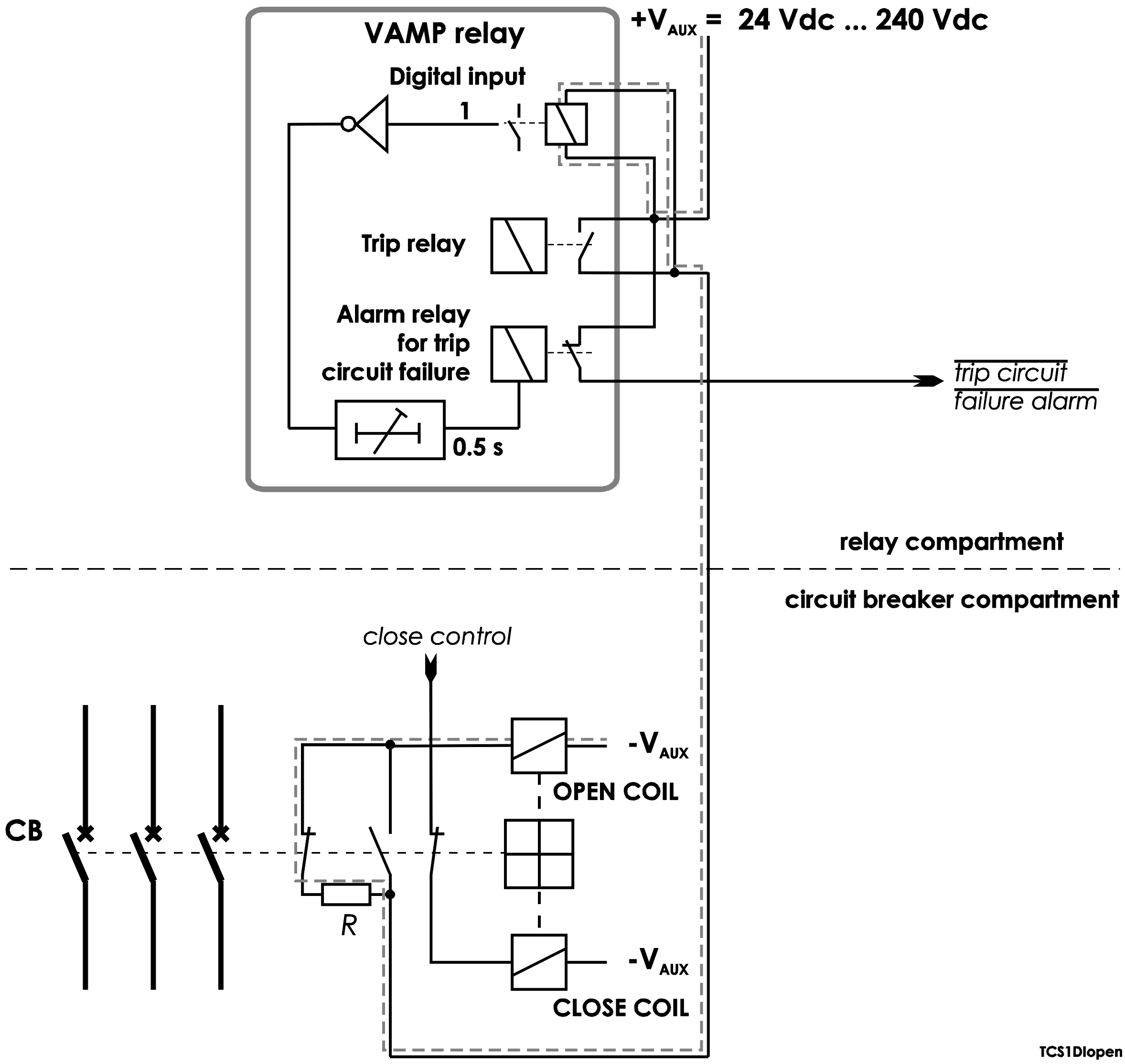
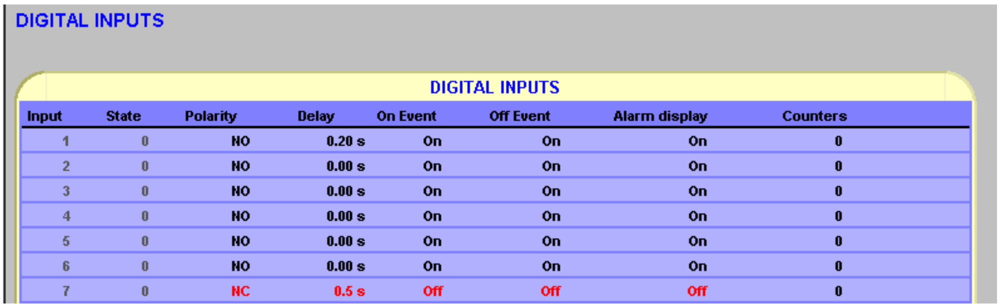


Figure 10.4.1-2 Trip circuit supervision using a single dry digital input, when the circuit breaker is in open position.

Note: If for example DI7 is used for trip circuit supervision, the usage of DI8 ... DI14 is limited to the same circuitry sharing the V_{AUX} in the common terminal.


DIGITAL INPUTS

DIGITAL INPUTS

Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	0	NO	0.20 s	On	On	On	0
2	0	NO	0.00 s	On	On	On	0
3	0	NO	0.00 s	On	On	On	0
4	0	NO	0.00 s	On	On	On	0
5	0	NO	0.00 s	On	On	On	0
6	0	NO	0.00 s	On	On	On	0
7	0	NC	0.5 s	Off	Off	Off	0

Figure 10.4.1-3 An example of digital input DI7 configuration for trip circuit supervision with one dry digital input.

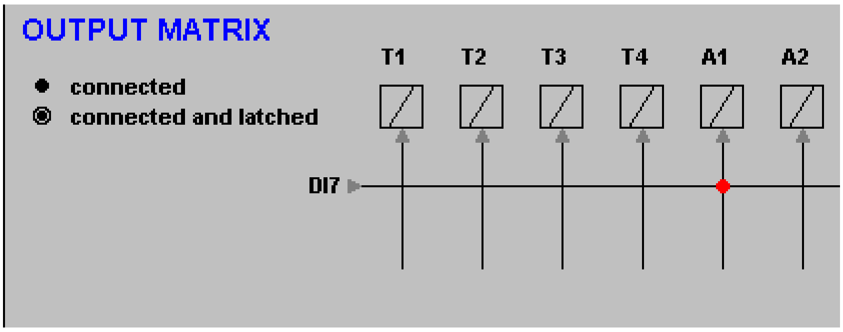


Figure 10.4.1-4 An example of output matrix configuration for trip circuit supervision with one dry digital input.

Example of dimensioning the external resistor R:

U_{AUX} = 110 Vdc –20 % + 10%
Auxiliary voltage with tolerance

U_{DI} = 18 Vdc
Threshold voltage of the digital input

I_{DI} = 3 mA
Typical current needed to activate the digital input including a 1 mA safety margin.

P_{Coil} = 50 W
Rated power of the open coil of the circuit breaker. If this value is not known, 0 Ω can be used for the R_{Coil}.

U_{MIN} = U_{AUX} – 20 % = 88 V

U_{MAX} = U_{AUX} + 10 % = 121 V

R_{Coil} = U^2_{AUX}/P = 242 Ω.

The external resistance value is calculated using Equation 10.4.1-1.

Equation 10.4.1-1

$$R = \frac{U_{MIN} - U_{DI} - I_{DI} \cdot R_{Coil}}{I_{DI}}$$

R = (88 – 18 – 0.003*242)/0.003 = 23.1 kΩ

(In practice the coil resistance has no effect.)

By selecting the next smaller standard size we get **22 kΩ**.

The power rating for the external resistor is estimated using Equation 10.4.1-2 and Equation 10.4.1-3. The Equation 10.4.1-2 is for the CB open situation including a 100 % safety margin to limit the maximum temperature of the resistor.

Equation 10.4.1-2

$$P = 2 \cdot I_{DI}^2 \cdot R$$

P = 2*0.003^2x22000 = 0.40 W

Select the next bigger standard size, for example **0.5 W**.

When the trip contacts are still closed and the CB is already open, the resistor has to withstand much higher power (Equation 10.4.1-3) for this short time.

Equation 10.4.1-3

$$P = \frac{U_{MAX}^2}{R}$$

P = 121^2/22000 = 0.67 W

A 0.5 W resistor will be enough for this short time peak power, too. However, if the trip relay is closed for longer time than a few seconds, a 1 W resistor should be used.

Using any of the non-dry digital inputs DI1...DI6

In this scheme an auxiliary relay is needed to connect the wet digital input to the trip circuit (Figure 10.4.1-5). The rated coil voltage of the auxiliary relay is selected according the rated auxiliary voltage used in the trip circuit. The operating voltage range of the relay should be as wide as possible to cover the tolerance of the auxiliary voltage.

In this application using the other wet inputs for other purposes is not limited unlike, when using the dry inputs.

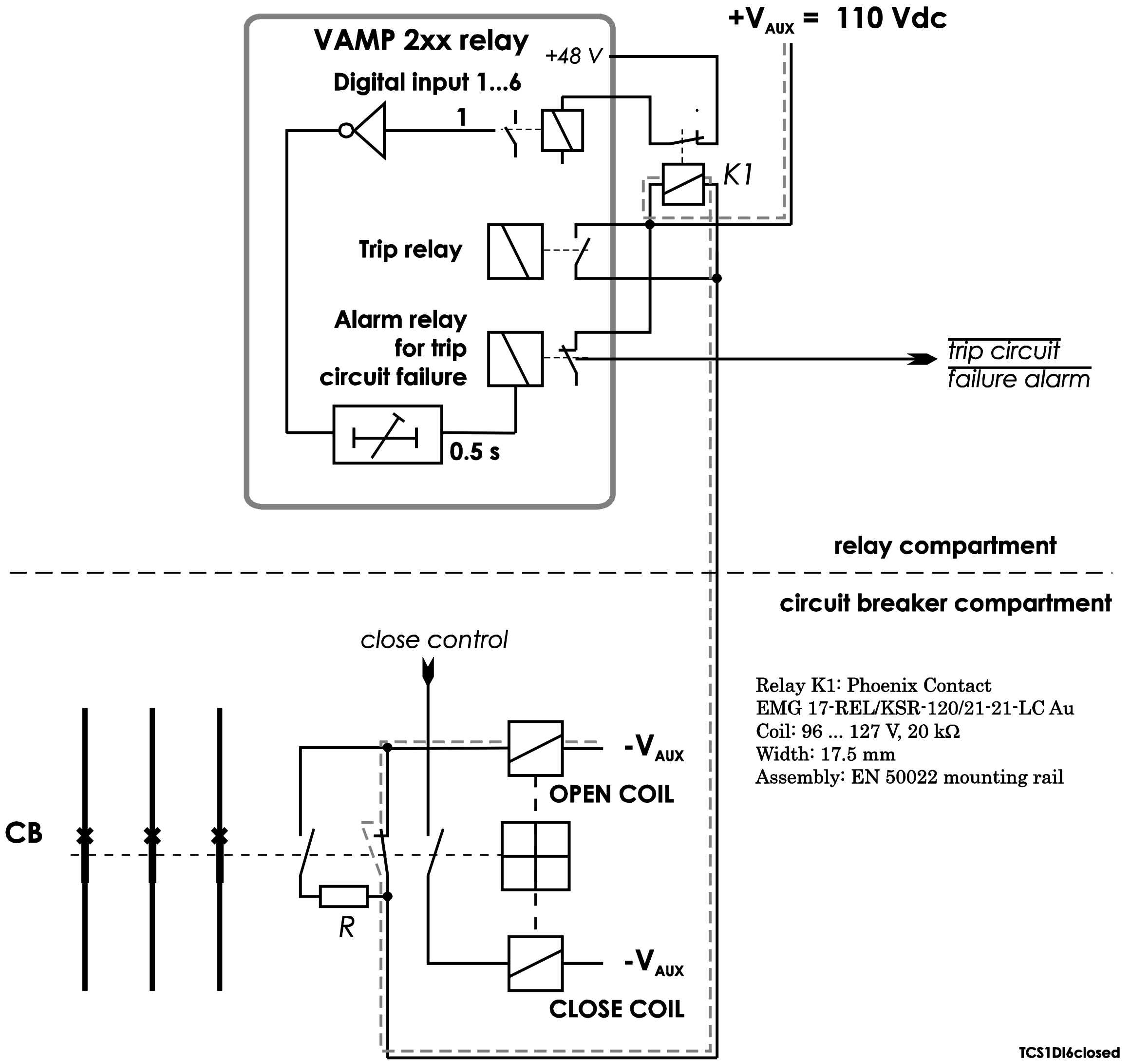
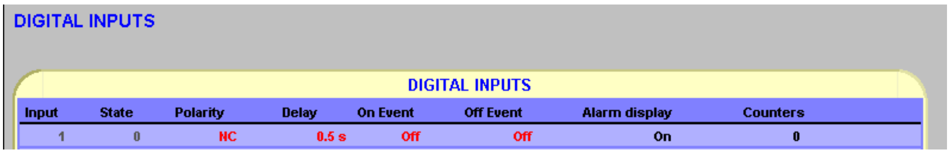


Figure 10.4.1-5 Trip circuit supervision using one of the VAMP 200 series internally wetted digital input (DI1...DI6) and auxiliary relay K1 and an external resistor R. The circuit-breaker is in the closed position. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete.



DIGITAL INPUTS

DIGITAL INPUTS

Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	0	NC	0.5 s	Off	Off	On	0

Figure 10.4.1-6 An example of digital input DI1 configuration for trip circuit supervision with one wet digital input.

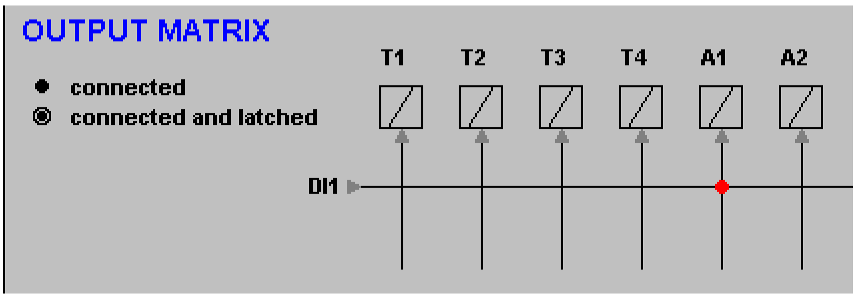


Figure 10.4.1-7 An example of output matrix configuration for trip circuit supervision with one wet digital input.

Example of dimensioning the external resistor R:

U_{AUX} = 110 Vdc –5 % + 10%

Auxiliary voltage with tolerance. Short time voltage dips more than 5 % are not critical from the trip circuit supervision point of view.

Relay type for the K1 auxiliary relay:

Phoenix Contact 2941455

EMG 17-REL/KSR-120/21-21-LC Au

U_{K1} = 120 Vac/dc –20 % + 10%

Coil voltage of the auxiliary relay K1

I_{K1} = 6 mA

Nominal coil current of the auxiliary relay K1

P_{CBcoil} = 50 W

Rated power of the open coil of the circuit breaker.

U_{MIN} = U_{AUX} – 5 % = 104.5 V

U_{MAX} = U_{AUX} + 10 % = 121 V

U_{K1MIN} = U_{K1} – 10 % = 96 V

R_{K1Coil} = U_{K1}/I_{K1} = 20 kΩ.

I_{K1MIN} = U_{K1MIN}/R_{K1Coil} = 4.8 mA

I_{K1MAX} = U_{K1MAX}/R_{K1Coil} = 6.1 mA

R_{CBCoil} = U^2_{AUX}/P = 242 Ω.

The external resistance value is calculated using Equation 10.4.1-4.

Equation 10.4.1-4

$$R = \frac{U_{MIN} - U_{K1MIN}}{I_{K1MIN}} - R_{Coil}$$

R = (104.5 – 96)/0.0048 - 242 = 1529 Ω

By selecting the next smaller standard size we get **1.5 kΩ**.

The power rating for the external resistor is calculated using Equation 10.4.1-5. This equation includes a 100 % safety margin to limit the maximum temperature of the resistor, because modern resistors are extremely hot at their rated maximum power.

Equation 10.4.1-5

$$P = 2 \cdot I^2_{K1MAX} \cdot R$$

P = 2*0.0061^2x1500 = 0.11 W

Select the next bigger standard size, for example 0.5 W.

When the trip contacts are still closed and the CB is already open, the resistor has to withstand much higher power (Equation 10.4.1-3) for this short time.

P = 121^2/1500 = 9.8 W

A **1 W** resistor should be selected to withstand this short time peak power. However, if the trip relay can be closed for longer time than a few seconds, a 20 W resistor should be used.

10.4.2. Trip circuit supervision with DI19 and DI20

The benefits of this scheme is that no external resistor is needed.

The drawbacks are, that two digital inputs from two separate groups are needed and two extra wires from the relay to the CB compartment is needed. Additionally the minimum allowed auxiliary voltage is 48 Vdc, which is more than twice the threshold voltage of the dry digital input, because when the CB is in open position, the two digital inputs are in series.

- The first digital input is connected parallel with the auxiliary contact of the open coil of the circuit breaker.
- Another auxiliary contact is connected in series with the circuitry of the first digital input. This makes it possible to supervise also the auxiliary contact in the trip circuit.
- The second digital input is connected in parallel with the trip contacts.
- Both inputs are configured as normal closed (NC).
- The user's programmable logic is used to combine the digital input signals with an AND port. The delay is configured longer than maximum fault time to inhibit any superfluous trip circuit fault alarm when the trip contact is closed.
- The output from the logic is connected to a relay in the output matrix giving out any trip circuit alarm.
- The trip relay should be configured as non-latched. Otherwise, a superfluous trip circuit fault alarm will follow after the trip contact operates, and the relay remains closed because of latching.
- Both digital inputs must have their own common potential. Using the other digital inputs in the same group as the upper DI in the Figure 10.4.2-1 is not possible in most applications. Using the other digital inputs in the same group as the lower DI in the Figure 10.4.2-1 is limited, because the whole group will be tied to the auxiliary voltage V_{AUX}.

Note: In many applications the optimum digital inputs for trip circuit supervision are the optional inputs DI19 and DI20 because they don't share their terminals with any other digital inputs.

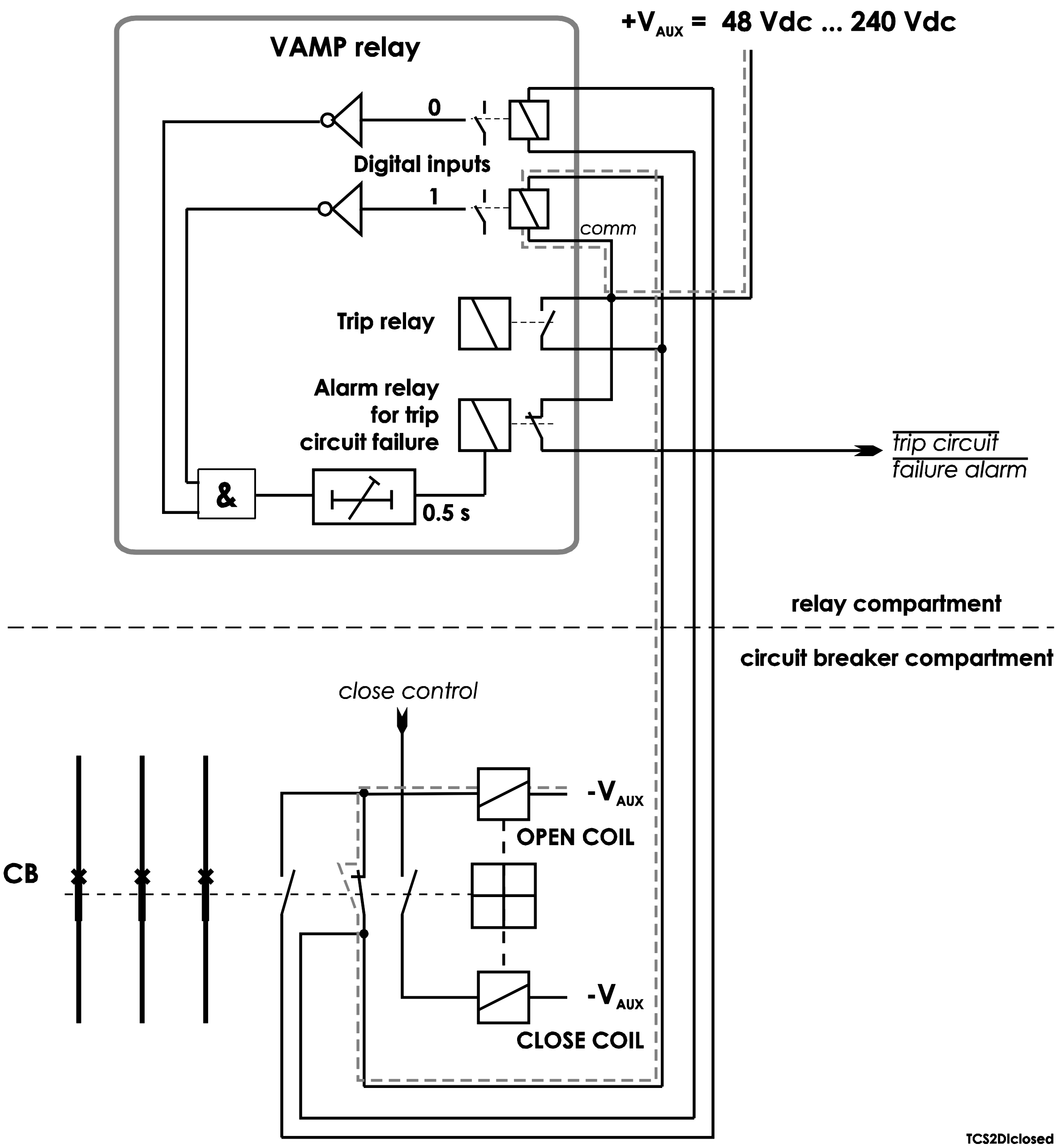


Figure 10.4.2-1 Trip circuit supervision with two dry digital input. The CB is closed. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete. This is applicable for dry inputs DI7...D20 only.

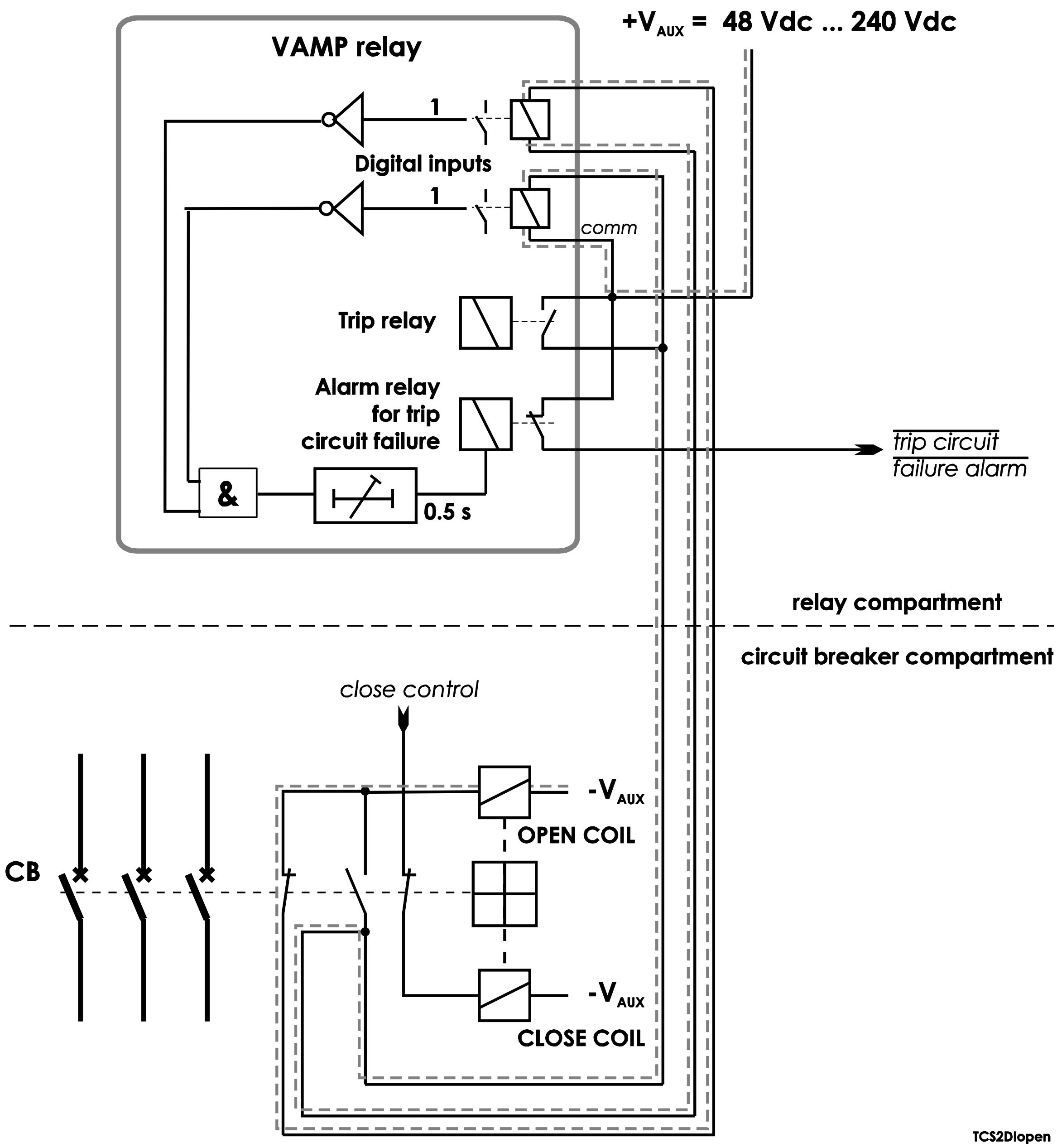
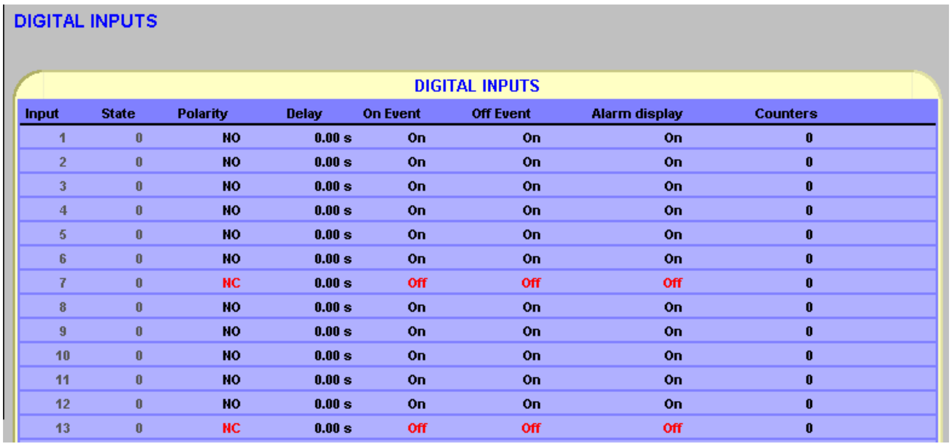


Figure 10.4.2-2 Trip circuit supervision with two dry digital inputs. The CB is in the open position. The two digital inputs are now in series.

Note: If for example DI13 and DI7 are used as the upper and lower digital inputs in the Figure 10.4.2-2, the usage of DI8 ... DI14 is limited to the same circuitry sharing the V_{AUX} in the common terminal and the DI14 ... DI18 cannot be used, because they share the same common terminal with DI13.



DIGITAL INPUTS

DIGITAL INPUTS

Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	0	NO	0.00 s	On	On	On	0
2	0	NO	0.00 s	On	On	On	0
3	0	NO	0.00 s	On	On	On	0
4	0	NO	0.00 s	On	On	On	0
5	0	NO	0.00 s	On	On	On	0
6	0	NO	0.00 s	On	On	On	0
7	0	NC	0.00 s	Off	Off	Off	0
8	0	NO	0.00 s	On	On	On	0
9	0	NO	0.00 s	On	On	On	0
10	0	NO	0.00 s	On	On	On	0
11	0	NO	0.00 s	On	On	On	0
12	0	NO	0.00 s	On	On	On	0
13	0	NC	0.00 s	Off	Off	Off	0

Figure 10.4.2-3 An example of digital input configuration for trip circuit supervision with two dry digital inputs DI7 and DI13.

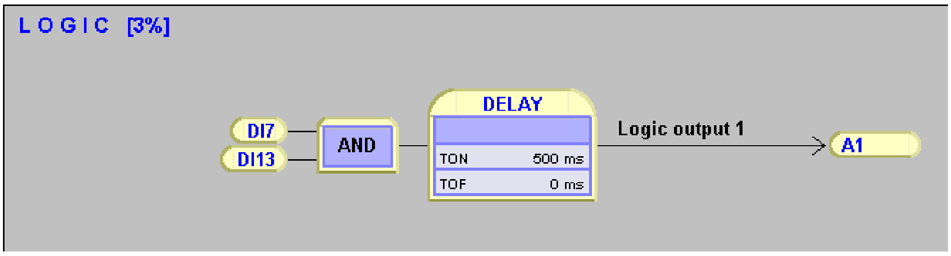


Figure 10.4.2-4 An example of logic configuration for trip circuit supervision with two dry digital inputs DI7 and DI13.

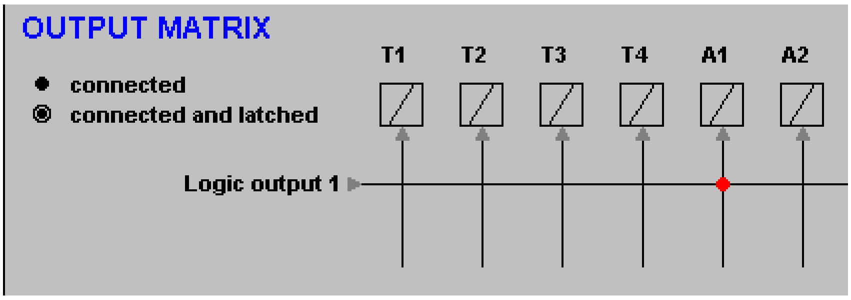


Figure 10.4.2-5 An example of output matrix configuration for trip circuit supervision with two dry digital inputs.

11. Connections

11.1. Rear panel view

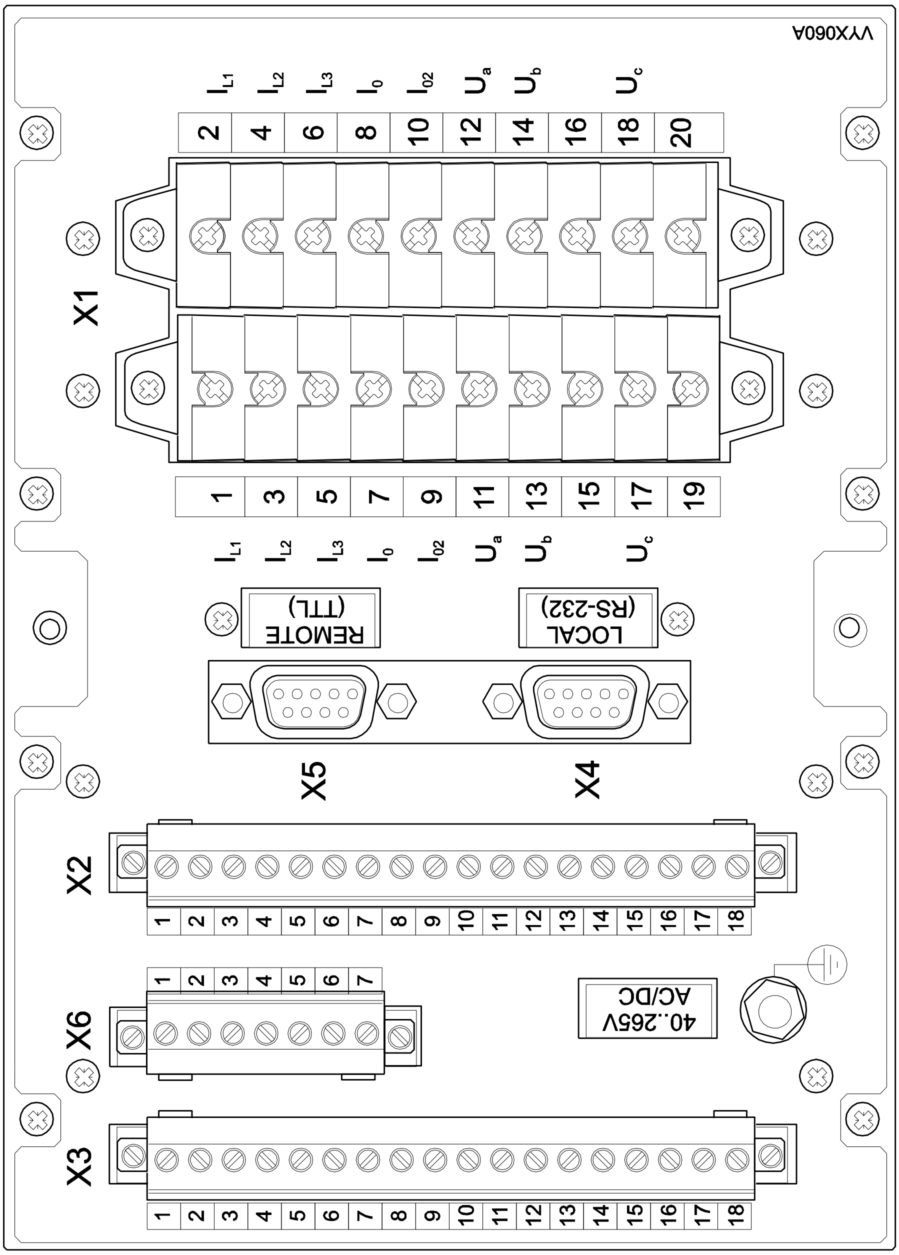
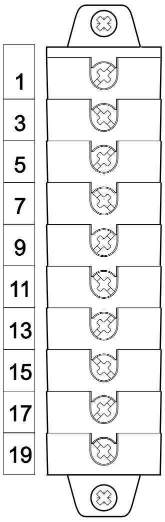


Figure 11.1-1 Connections on the rear panel of the VAMP 210

The generator protection relay is connected to the protected object through the following measuring and control connections.

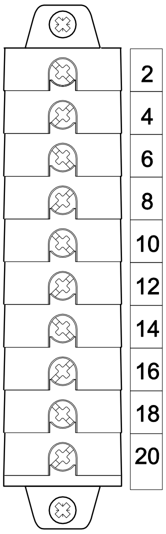
- Phase currents IL1, IL2 and IL3 (terminals X1: 1-6)
- Residual currents I01 and I02 (terminals X1: 7-10)
- Phase-to-phase voltages U12 and U23 (terminals X1: 11-14)
- Zero sequence voltage U0 (terminals X1: 17-18)

Terminal X1 left side



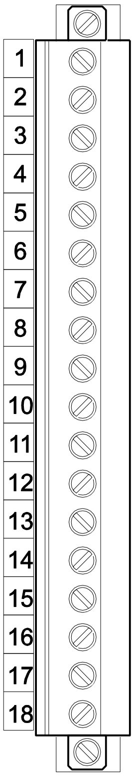
No:	Symbol	Description
1	IL1 (S1)	Phase current L1 (S1)
3	IL2 (S1)	Phase current L2 (S1)
5	IL3 (S1)	Phase current L3 (S1)
7	Io1 (S1)	Residual current Io1 (S1)
9	Io2 (S1)	Residual current Io2 (S1)
11	Ua (a)	Line-to-line voltage U12 (a) or phase-to-neutral voltage UL1 (a)
13	Ub (a)	Line-to-line voltage U23 (a) or phase-to-neutral voltage UL2 (a)
15	--	--
17	Uc (dn,n)	Zero sequence voltage Uo (dn) or phase-to-neutral voltage UL3 (b)
19	--	--

Terminal X1 right side



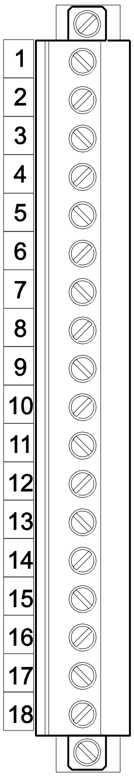
No:	Symbol	Description
2	IL1 (S2)	Phase current L1 (S2)
4	IL2 (S2)	Phase current L2 (S2)
6	IL3 (S2)	Phase current L3 (S2)
8	Io1 (S2)	Residual current Io1 (S2)
10	Io2 (S2)	Residual current Io2 (S2)
12	Ua (b,n)	Line-to-line voltage U12 (b) or phase-to-neutral voltage UL1 (n)
14	Ub (b,n)	Line-to-line voltage U23 (b) or phase-to-neutral voltage UL2 (n)
16	--	--
18	Uc (da,a)	Zero sequence voltage Uo (da) or phase-to-neutral voltage UL3 (a)
20	--	--

Terminal X2 without the analogue output



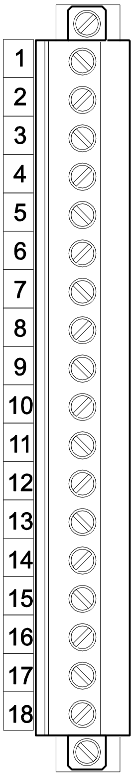
No:	Symbol	Description
1	--	--
2	--	--
3	--	--
4	--	--
5	A5	Alarm relay 5
6	A5	Alarm relay 5
7	A4	Alarm relay 4
8	A4	Alarm relay 4
9	--	--
10	A3 COM	Alarm relay 3, common connector
11	A3 NC	Alarm relay 3, normal closed connector
12	A3 NO	Alarm relay 3, normal open connector
13	A2 COM	Alarm relay 2, common connector
14	A2 NC	Alarm relay 2, normal closed connector
15	A2 NO	Alarm relay 2, normal open connector
16	IF COM	Internal fault relay, common connector
17	IF NC	Internal fault relay, normal closed connector
18	IF NO	Internal fault relay, normal open connector

Terminal X2 with the analogue output



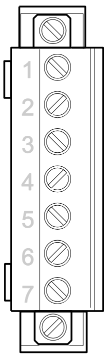
No:	Symbol	Description
1	AO1+	Analogue output 1, common positive connector
2	AO1–	Analogue output 1, negative connector
3	AO2+	Analogue output 2, common positive connector
4	AO2–	Analogue output 2, negative connector
5	AO3+	Analogue output 3, common positive connector
6	AO3–	Analogue output 3, negative connector
7	AO4+	Analogue output 4, common positive connector
8	AO4–	Analogue output 4, negative connector
9	--	--
10	A3 COM	Alarm relay 3, common connector
11	A3 NC	Alarm relay 3, normal closed connector
12	A3 NO	Alarm relay 3, normal open connector
13	A2 COM	Alarm relay 2, common connector
14	A2 NC	Alarm relay 2, normal closed connector
15	A2 NO	Alarm relay 2, normal open connector
16	IF COM	Internal fault relay, common connector
17	IF NC	Internal fault relay, normal closed connector
18	IF NO	Internal fault relay, normal open connector

Terminal X3



No:	Symbol	Description
1	+48V	Internal wetting voltage for digital inputs 1 – 6
2	DI1	Digital input 1
3	DI2	Digital input 2
4	DI3	Digital input 3
5	DI4	Digital input 4
6	DI5	Digital input 5
7	DI6	Digital input 6
8	--	--
9	A1 COM	Alarm relay 1, common connector
10	A1 NO	Alarm relay 1, normal open connector
11	A1 NC	Alarm relay 1, normal closed connector
12	T2	Trip relay 2
13	T2	Trip relay 2
14	T1	Trip relay 1
15	T1	Trip relay 1
16	--	--
17	Uaux	Auxiliary voltage
18	Uaux	Auxiliary voltage

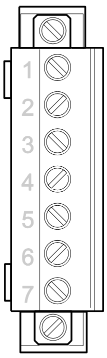
Terminal X6



No:	Symbol	Description
1	BI	External arc light input
2	BO	Arc output
3	COM	Common for BI and BO
4	S1>+	Arc sensor 1, positive connector *
5	S1>–	Arc sensor 1, negative connector *
6	S2>+	Arc sensor 2, positive connector *
7	S2>–	Arc sensor 2, negative connector *

*) Arc sensor itself is polarity free

Terminal X6 with DI19/DI20 option



No:	Symbol	Description
1	DI19	Digital input 19
2	DI19	Digital input 19
3	DI20	Digital input 20
4	DI20	Digital input 20
5	--	--
6	S1>+	Arc sensor 1, positive connector *
7	S1>–	Arc sensor 1, negative connector *

*) Arc sensor itself is polarity free

11.2. Auxiliary voltage

The external auxiliary voltage U_{aux} (standard 40…265 V ac/dc or optional 18…36 Vdc) for the terminal is connected to the terminals X3: 17-18.

NOTE! When optional 18…36 Vdc power module is used the polarity is as follows:

X3:17 negative, X3:18 positive.

11.3. Output relays

The terminal is equipped with nine configurable output relays, and a separate output relay for the self-supervision system.

- Trip relays T1 and T2 (terminals X3: 12-13 and 14-15)
- Alarm relays A1 - A5 (terminals X3: 9-11, X2: 5-6, 7-8, 10-12, 13-15)
- Self-supervision system output relay IF (terminals X2: 16-18)

11.4. Serial communication connectors

The pin assignments of communication connectors including internal communication converters are presented in the following figures and tables.

11.4.1. Front panel connector

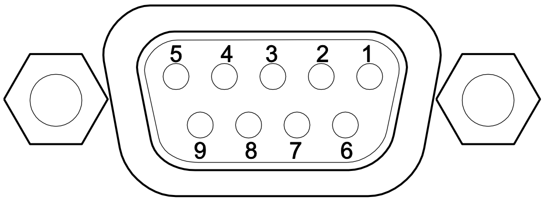


Figure 11.4.1-1 Pin numbering of the front panel D9S connector

Pin	RS232 signal
1	Not connected
2	Rx in
3	Tx out
4	DTR out (+8 V)
5	GND
6	DSR in (activates this port and disables the X4 RS232 port)
7	RTS in (Internally connected to pin 8)
8	CTS out (Internally connected to pin 7)
9	No connected

NOTE! DSR must be connected to DTR to activate the front panel connector and disable the rear panel X4 RS232 port. (The other port in the same X4 connector will not be disabled.)

11.4.2. Rear panel connector X5 (REMOTE)

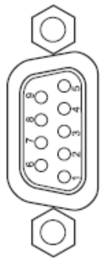
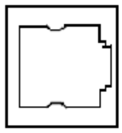
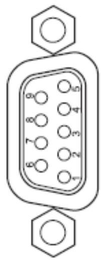
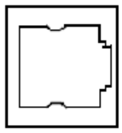
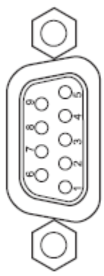
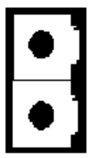
The X5 remote port communication connector options are shown in Figure 11.4.2-1. The connector types are listed in Table 11.4.2-1.

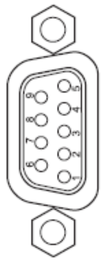
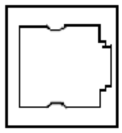
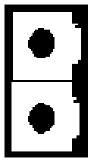
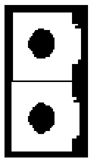
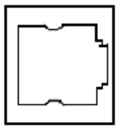
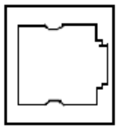
Without any internal options, X5 is a TTL port for external converters. Some external converters (VSE) are attached directly to the rear panel and X5. Some other types (VEA, VPA) need various TTL/RS-232 converter cables. The available accessories are listed in chapter 15.

Internal options for fibre optic (Figure 11.4.2-3), 2&4-wire galvanically isolated RS-485 (Figure 11.4.2-2) and Profibus (Figure 11.4.2-4) are available. See ordering code in chapter 15.

Table 11.4.2-1 Physical interface and connector types of remote port X5 with various options. Serial interface (A) is the default.

Order Code	Communication interface	Connector type	Pin usage
A	Serial interface for external converters only (REMOTE port)	D9S	1 = reserved 2 = TX_out / TTL 3 = RX_in /TTL 4 = RTS out /TTL 7 = GND 9 = +8V out
B	Plastic fibre interface (REMOTE port)	HFBR-0500	
C	Profibus interface (REMOTE port)	D9S	3=RXD/TXD+/P 4=RTS 5= GND 6=+5V 8= RXD/TXD-/N
D	RS-485, isolated (REMOTE port)	screw terminal	1= Signal ground 2= Reciever - 3= Reciever + 4= Transmitter - 5= Transmitter +
E	Glass fibre interface (62.5/125 μm) (REMOTE port)	ST	
F	Plastic / glass (62.5/125 μm) fibre interface (REMOTE port)	HFBR-0500/ST	Plastic Rx Glass Tx
G	Glass (62.5/125 μm) / plastic fibre interface (REMOTE port)	ST/HFBR-0500	Glass Rx Plastic Tx

Order Code	Communication interface	Connector type	Pin usage
H	Ethernet interface and Serial interface for external converters only (REMOTE port)	D9S and RJ-45  	D-connector: 1 = reserved 2 = TX_out / TTL 3 = RX_in /TTL 4 = RTS out /TTL 7 = GND 9 = +8V out RJ-45 connector : 1=Transmit+ 2=Transmit- 3=Receive+ 4=Reserved 5=Reserved 6=Receive- 7=Reserved 8=Reserved
M	10Mbps Ethernet interface with IEC 61850 and Serial interface for external converters only (REMOTE port)	D9S and RJ-45  	D-connector: 1 = reserved 2 = TX_out / TTL 3 = RX_in /TTL 4 = RTS out /TTL 7 = GND 9 = +8V out RJ-45 connector : 1=Transmit+ 2=Transmit- 3=Receive+ 4=Reserved 5=Reserved 6=Receive- 7=Reserved 8=Reserved
O	100 Mbps Ethernet fibre interface with IEC 61850 and Serial interface for external converters only (REMOTE port)	D9S and LC  	D-connector: 1 = reserved 2 = TX_out / TTL 3 = RX_in /TTL 4 = RTS out /TTL 7 = GND 9 = +8V out Fiber connector: TX=Upper LC-connector RX=Lower LC-connector

Order Code	Communication interface	Connector type	Pin usage
P	100Mbps Ethernet interface with IEC 61850 and Serial interface for external converters only (REMOTE port)	D9S and RJ-45  	D-connector: 1 = reserved 2 = TX_out / TTL 3 = RX_in /TTL 4 = RTS out /TTL 7 = GND 9 = +8V out RJ-45 connector : 1=Transmit+ 2=Transmit- 3=Receive+ 4=Reserved 5=Reserved 6=Receive- 7=Reserved 8=Reserved
R	100 Mbps Ethernet fibre interface with IEC 61850	2 x LC  	LC-connector from top: -Port 2 Tx -Port 2 Rx -Port 1 Tx -Port 1 Rx
S	100Mbps Ethernet interface with IEC 61850	2 x RJ-45  	1=Transmit+ 2=Transmit- 3=Receive+ 4=Reserved 5=Reserved 6=Receive- 7=Reserved 8=Reserved

NOTE! In the VAMP relays RS485 interfaces a positive voltage from Tx+ to Tx– or Rx+ to Rx– does correspond to the bit value “1”. In X5 connector the optional RS485 is galvanically isolated.

NOTE! In 2-wire mode the receiver and transmitter are internally connected in parallel. See a table below.

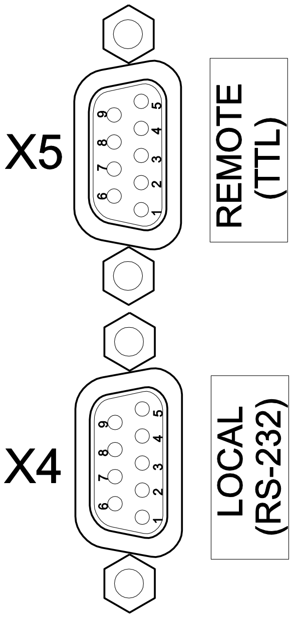


Figure 11.4.2-1 Pin numbering of the rear communication ports, REMOTE TTL

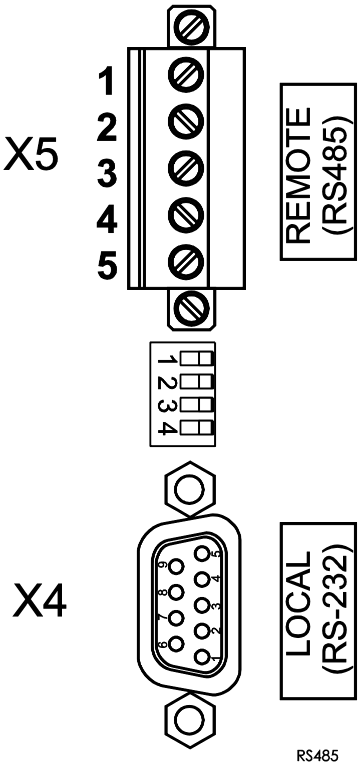


Figure 11.4.2-2 Pin numbering of the rear communication ports, REMOTE RS-485.

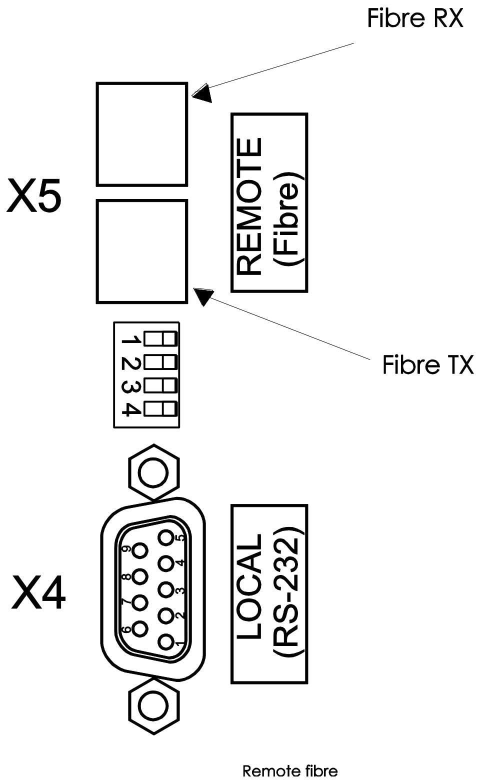


Figure 11.4.2-3 Picture of rear communication port, REMOTE FIBRE.

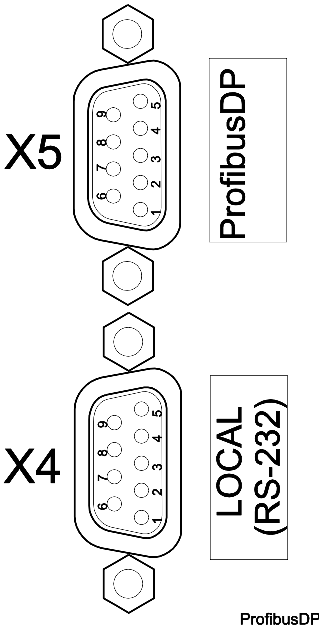


Figure 11.4.2-4 Pin numbering of the rear communication ports, Profibus DP.

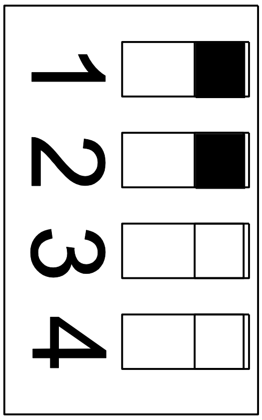


Figure 11.4.2-5 Dip switches in RS-485 and optic fibre options.

Dip switch number	**Switch position**	**Function RS-485**	**Function Fibre optics**
1	Left	2 wire connection	Echo off
1	Right	4 wire connection	Echo on
2	Left	2 wire connection	Light on in idle state
2	Right	4 wire connection	Light off in idle state
3	Left	Termination On	Not applicable
3	Right	Termination Off	Not applicable
4	Left	Termination On	Not applicable
4	Right	Termination Off	Not applicable

11.4.3. X4 rear panel connector (local RS232 and extension RS485 ports)

Rear panel port (LOCAL)	Pin	Signal
X4	1	No connection
X4	2	Rx in, RS232 local
X4	3	Tx out, RS232 local
X4	4	DTR out (+8 V)
X4	5	GND
X4	6	No connection
X4	7	B− RS485 extension port
X4	8	A+ RS485 extension port
X4	9	No connection

NOTE! In the VAMP relays a positive RS485 voltage from A+ to B− corresponds to bit value “1”. In X4 connector the RS485 extension port is not galvanically isolated.

11.5. Optional two channel arc protection card

NOTE! When this option card is installed, the parameter "Arc card type" has value "2Arc+BI/O". Please check the ordering code in chapter 15.

NOTE! If the slot X6 is already occupied with the DI19/DI20 digital input card, this option is not available, but there is still one arc sensor channel available. See chapter 11.6

The optional arc protection card includes two arc sensor channels. The arc sensors are connected to terminals X6: 4-5 and 6-7.

The arc information can be transmitted and/or received through digital input and output channels. This is a 48 V dc signal.

Connections:

X6: 1	Binary input (BI)
X6: 2	Binary output (BO)
X6: 3	Common for BI and BO.
X6: 4-5	Sensor 1
X6: 6-7	Sensor 2

The binary output of the arc option card may be activated by the arc sensors or by any available signal in the output matrix. The binary output can be connected to an arc binary input of another VAMP protection relay or manager.

11.6. Optional digital I/O card (DI19/DI20)

NOTE! When this option card is installed, the parameter "Arc card type" has value "Arc+2DI". With DI19/DI20 option only one arc sensor channel is available. Please check the ordering code in chapter 15.

NOTE! If the slot X6 is already occupied with the two channel arc sensor card (chapter 11.5), this option is not available.

The DI19/DI20 option enables two more digital inputs. These inputs are useful in applications where the contact signals are not potential free. For example trip circuit supervision is such application. The inputs are connected to terminals X6:1 – X6:2 and X6:3 – X6:4.

Connections:

X6:1	DI19+
X6:2	DI19-
X6:3	DI20+
X6:4	DI20-
X6:5	NC
X6:6	L+
X6:7	L-

11.7. External I/O extension modules

11.7.1. External LED module VAM 16D

The optional external VAM 16D led module provides 16 extra led-indicators in external casing. Module is connected to the serial port of the relays front panel. Please refer the User manual VAM 16 D, VM16D.ENxxx for details.

11.7.2. External input / output module

The relay supports an optional external input/output modules used to extend the number of digital inputs and outputs. Also modules for analogue inputs and outputs are available. The following types of devices are supported:

- Analog input modules (RTD)
- Analog output modules (mA-output)
- Binary input/output modules

EXTENSION port is primarily designed for IO modules. This port is found in the LOCAL connector of the relay backplane and IO devices should be connected to the port with VSE003 adapter.

NOTE! If ExternalIO protocol is not selected to any communication port, VAMPSET doesn’t display the menus required for configuring the IO devices. After changing EXTENSION port protocol to ExternalIO, restart the relay and read all settings with VAMPSET.

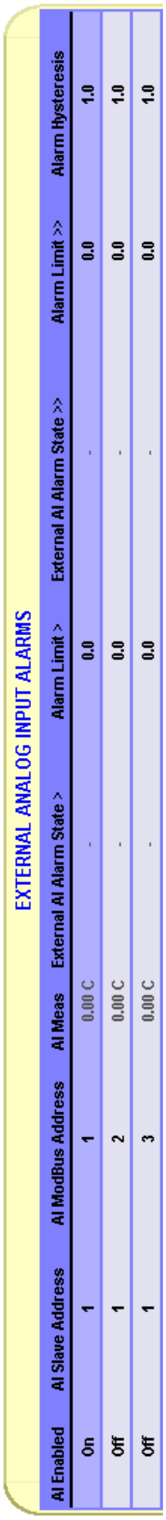
External analog inputs configuration (VAMPSET only)


EXTERNAL ANALOG INPUTS

AI Enabled	AI Meas	AI Unit	AI Slave Address	AI ModBus Address	AI Register Type	AI Offset	x1	y1	x2	y2	AI Error Counter
On	0.00 C	C	1	1	HoldingR	0	0	0	1	1	0
Off	0.00 C	C	1	2	HoldingR	0	0	0	1	1	0
Off	0.00 C	C	1	3	HoldingR	0	0	0	1	1	0

<table>
<tr><th>Range</th><th colspan="4">Description</th></tr>
<tr><td></td><td colspan="4">Communication read errors</td></tr>
<tr><td rowspan="4">X: -32000…32000
Y: -1000…1000</td><td rowspan="5">Scaling</td><td>Y2</td><td>Scaled value</td><td rowspan="2">Point 2</td></tr>
<tr><td>X2</td><td>Modbus value</td></tr>
<tr><td>Y1</td><td>Scaled value</td><td rowspan="2">Point 1</td></tr>
<tr><td>X1</td><td>Modbus value</td></tr>
<tr><td>-32000…32000</td><td>Off set</td><td colspan="2">Subtracted from Modbus value, before running XY scaling</td></tr>
<tr><td>InputR or HoldingR</td><td colspan="4">Modbus register type</td></tr>
<tr><td>1…9999</td><td colspan="4">Modbus register for the measurement</td></tr>
<tr><td>1…247</td><td colspan="4">Modbus address of the I/O device</td></tr>
<tr><td>C, F, K, mA, Ohm or V/A</td><td colspan="4">Unit selection</td></tr>
<tr><td></td><td colspan="4">Active value</td></tr>
<tr><td>On / Off</td><td colspan="4">Enabling for measurement</td></tr>
</table>

Alarms for external analog inputs



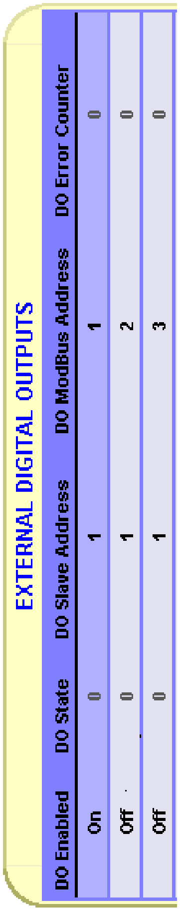
Range	Description	
0…10000	Hysteresis for alarm limits	
-21x107… …21x107	Alarm >>	Limit setting
- / Alarm		Active state
-21x107… …21x107	Alarm >	Limit setting
- / Alarm		Active state
	Active value	
1…9999	Modbus register for the measurement	
1…247	Modbus address of the I/O device	
On / Off	Enabling for measurement	

Analog input alarms have also matrix signals, “Ext. Aix Alarm1” and “Ext. Aix Alarm2”.

External digital inputs configuration (VAMPSET only)

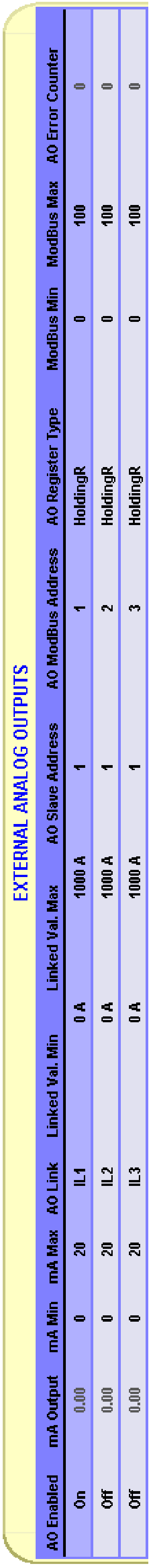
Range	Description
	Communication read errors
1…16	Bit number of Modbus register value
CoilS, InputS, InputR or HoldingR	Modbus register type
1…9999	Modbus register for the measurement
1…247	Modbus address of the I/O device
0 / 1	Active state
On / Off	Enabling for measurement

External digital outputs configuration (VAMPSET only)



Range	Description
	Communication errors
1…9999	Modbus register for the measurement
1…247	Modbus address of the I/O device
0 / 1	Output state
On / Off	Enabling for measurement

External analog outputs configuration (VAMPSET only)



Range	Description
	Communication errors
-32768…+32767 (0…65535)	Modbus value corresponding Linked Val. Max
	Modbus value corresponding Linked Val. Min
InputR or HoldingR	Modbus register type
1…9999	Modbus register for the output
1…247	Modbus address of the I/O device
0…42x108, -21…+21x108	Maximum limit for lined value, corresponding to “Modbus Max”
	Minimum limit for lined value, corresponding to “Modbus Min”
	Link selection
-21x107… …+21x107	Minimum & maximum output values
	Active value
On / Off	Enabling for measurement

11.8. Block diagrams

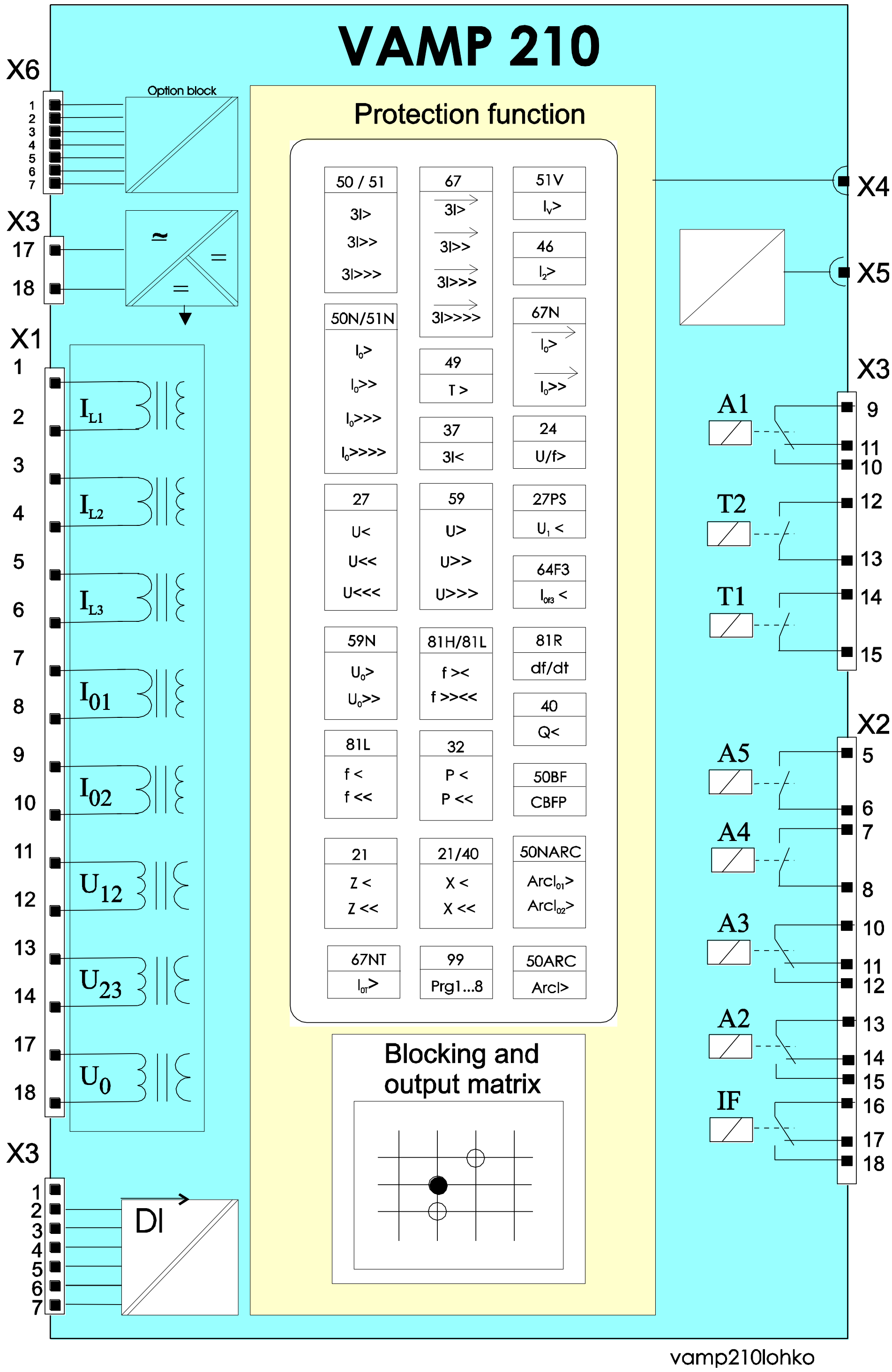


Figure 11.8-1 Block diagram of the generator protection relay VAMP 210

11.9. Block diagrams of option modules

11.9.1. Optional arc protection

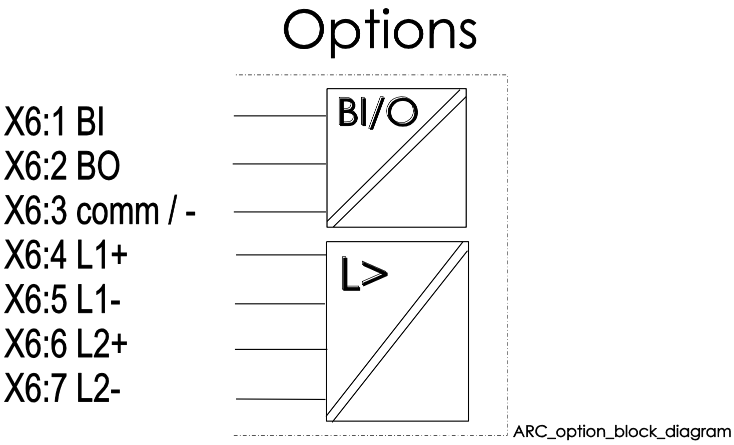


Figure 11.9.1-1 Block diagram of optional arc protection module.

11.9.2. Optional DI19/DI20

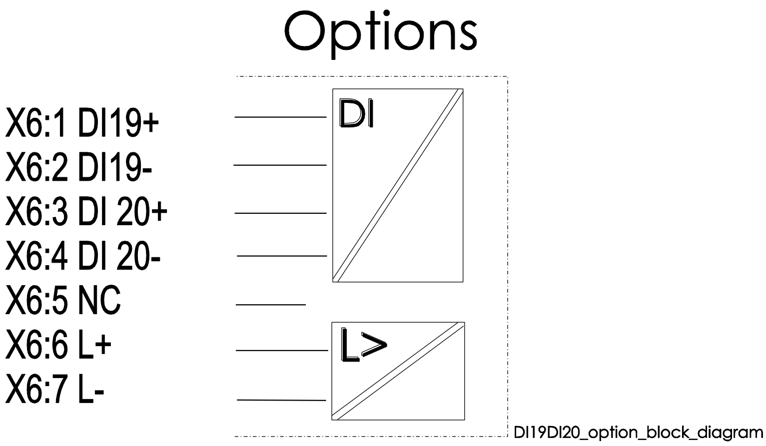


Figure 11.9.2-1 Block diagram of optional DI19/DI20 module with one arc channel.

11.10. Connection examples

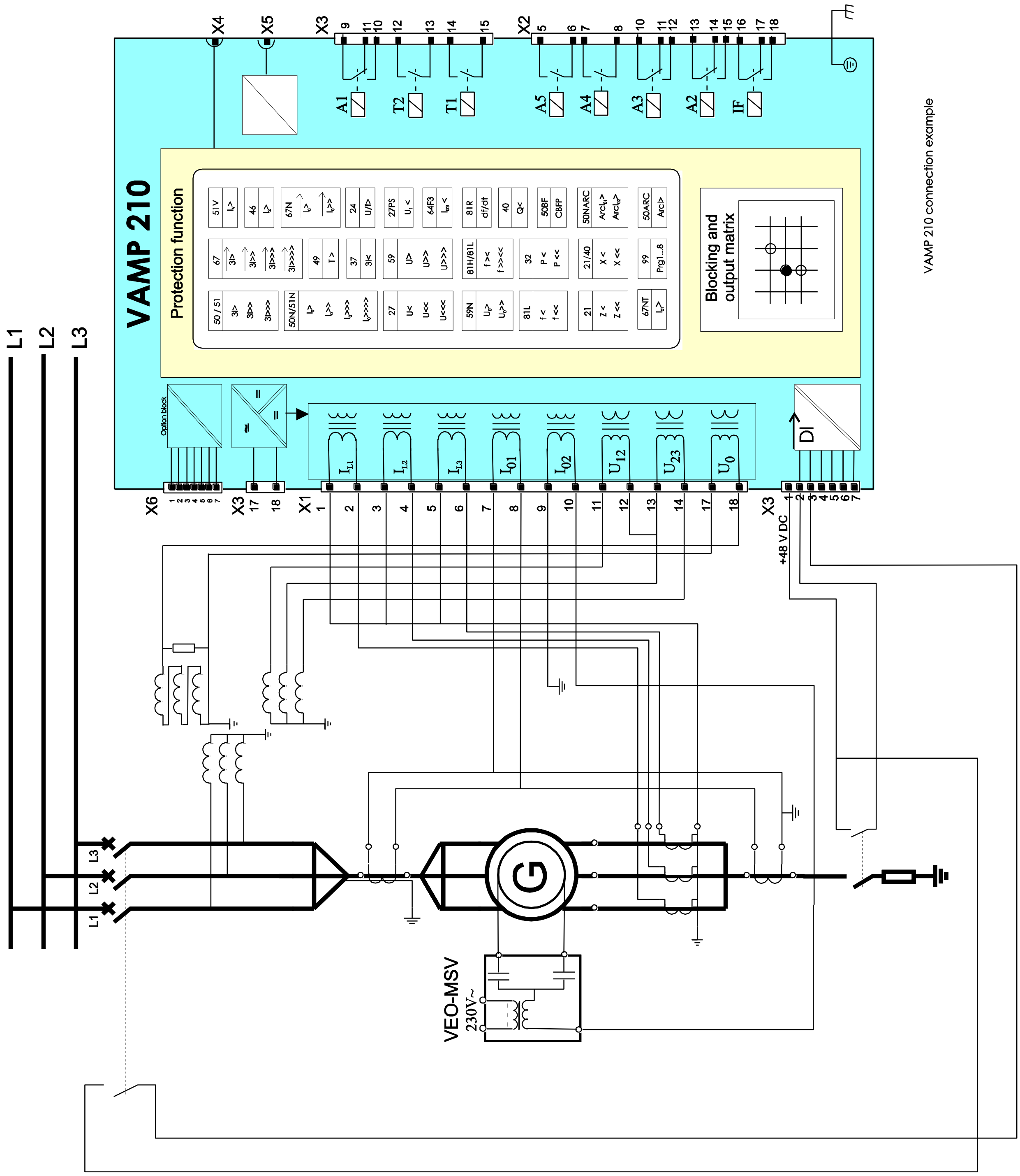


Figure 11.10-1 Connection example of VAMP 210.

12. Technical data

12.1. Connections

12.1.1. Measuring circuitry

Rated phase current - Current measuring range - Thermal withstand - Burden	5 A (configurable for CT secondaries 1 – 10 A) 0…250 A 20 A (continuously) 100 A (for 10 s) 500 A (for 1 s) < 0.2 VA
Rated phase current (optional) - Current measuring range - Thermal withstand - Burden	1 A (configurable for CT secondaries 1 – 10 A) 0…50 A 20 A (continuously) 100 A (for 10 s) 500 A (for 1 s) < 0.1 VA
Rated residual current (optional) - Current measuring range - Thermal withstand - Burden	5 A (configurable for CT secondaries 1 – 10 A) 0…25 A 4 A (continuously) 20 A (for 10 s) 100 A (for 1 s) < 0.2 VA
Rated residual current - Current measuring range - Thermal withstand - Burden	1 A (configurable for CT secondaries 0.1 – 10.0 A) 0…5 A 4 A (continuously) 20 A (for 10 s) 100 A (for 1 s) < 0.1 VA
Rated voltage U_n - Voltage measuring range - Continuous voltage withstand - Burden	100 V (configurable for VT secondaries 50 – 120 V) 0 – 160 V (100 V/110 V) 250 V < 0.5V A
Rated frequency f_n	45 – 65 Hz
Terminal block: - Solid or stranded wire	Maximum wire dimension: 4 mm^2 (10-12 AWG)

12.1.2. Auxiliary voltage

	Type A	Type B
Voltage range U_{aux}	40 - 265 V ac/dc	18...36 Vdc Note! Polarity. X3:17= negative (-) X3:18= positive (+)
Start-up peak (DC) 110V (Type A) 220V (Type A)	 15A with time constant of 1ms 25A with time constant of 1ms	
Power consumption Max. permitted interruption time	< 7 W (normal conditions) < 15 W (output relays activated) < 50 ms (110 V dc)	
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm^2 (13-14 AWG)	

12.1.3. Digital inputs

Internal operating voltage

Number of inputs	6
Internal operating voltage	48 Vdc
Current drain when active (max.)	approx. 20 mA
Current drain, average value	< 1 mA
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm^2 (13-14 AWG)

12.1.4. Trip contacts

Number of contacts	2 making contacts (relays T1 and T2)
Rated voltage	250 Vac/dc
Continuous carry	5 A
Make and carry, 0.5 s Make and carry, 3s	30 A 15 A
DC breaking capacity (L/R=40ms) at 48 VDC: at 110 VDC: at 220 VDC	 5 A 3 A 1 A
Contact material	AgNi 90/10
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm^2 (13-14 AWG)

12.1.5. Alarm contacts

Number of contacts	3 change-over contacts (relays A1, A2 and A3) 2 making contacts (relays A4 and A5) 1 change-over contact (IF relay)
Rated voltage	250 V ac/dc
Continuous carry	5 A
DC breaking capacity (L/R=40ms) at 48 VDC: at 110 VDC: at 220 VDC	 1,3 A 0,4 A 0,2 A
Contact material	AgNi 0.15 gold plated
Terminal block - Phoenix MVSTBW or equivalent	Maximum wire dimension 2.5 mm^2 (13-14 AWG)

12.1.6. Arc protection interface (option)

Number of arc sensor inputs Sensor type to be connected Operating voltage level Current drain, when active Current drain range	2 VA 1 DA 12 V dc > 11.9 mA 1.3…31 mA (**NOTE! If the drain is outside the range, either sensor or the wiring is defected**)
Number of binary inputs Operating voltage level	1 (optically isolated) +48 Vdc
Number of binary outputs Operating voltage level	1 (open collector) +48 Vdc

NOTE! Maximally three arc binary inputs can be connected to one arc binary output without an external amplifier.

12.2. Tests and environmental conditions

12.2.1. Disturbance tests

Emission (EN 50081-1) - Conducted (EN 55022B) - Emitted (CISPR 11)	 0.15 - 30 MHz 30 – 1 000 MHz
Immunity (EN 50082-2) - Static discharge (ESD) - Fast transients (EFT) - Surge - Conducted HF field - Emitted HF field - GSM test	 EN 61000-4-2, class III 6 kV contact discharge 8 kV air discharge EN 61000-4-4, class III 2 kV, 5/50 ns, 5 kHz, +/- EN 61000-4-5, class III 2 kV, 1.2/50 µs, common mode 1 kV, 1.2/50 µs, differential mode EN 61000-4-6 0.15 - 80 MHz, 10 V EN 61000-4-3 80 - 1000 MHz, 10 V/m ENV 50204 900 MHz, 10 V/m, pulse modulated

12.2.2. Dielectric test voltages

Insulation test voltage (IEC 60255-5) Class III	2 kV, 50 Hz, 1 min
Surge voltage (IEC 60255-5) Class III	5 kV, 1.2/50 µs, 0.5 J

12.2.3. Mechanical tests

Vibration (IEC 60255-21-1) Class I	10 ... 60 Hz, amplitude ±0.035 mm 60 ... 150 Hz, acceleration 0.5g sweep rate 1 octave/min 20 periods in X-, Y- and Z axis direction
Shock (IEC 60255-21-1) Class I	half sine, acceleration 5 g, duration 11 ms 3 shocks in X-, Y- and Z axis direction

12.2.4. Environmental conditions

Operating temperature	-10 to +55 °C
Transport and storage temperature	-40 to +70 °C
Relative humidity	< 75% (1 year, average value) < 90% (30 days per year, no condensation permitted)

12.2.5. Casing

Degree of protection (IEC 60529)	IP20
Dimensions (W x H x D)	208 x 155 x 225 mm 8.19 x 6.10 x 8.86 inches
Material	1 mm steel plate
Weight	4.2 kg
Colour code	RAL 7032 (Casing) / RAL 7035 (Back plate)

12.2.6. Package

Dimensions (W x H x D)	215 x 160 x 275 mm 8.46 x 6.30 x 10.82 inches
Weight (Terminal, Package and Manual)	5.2 kg

12.3. Protection functions

For setting values the step size is mentioned if it differs from the given resolution.

12.3.1. Current protection

Overcurrent stage I> (50/51)

Pick-up current	0.10 – 5.00 x I_{GN}
Definite time function: - Operating time	DT 0.08**) – 300.00 s (step 0.02 s)
IDMT function: - Delay curve family - Curve type - Time multiplier k	 (DT), IEC, IEEE, RI Prg EI, VI, NI, LTI, MI…depends on the family *) 0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time Reset time Retardation time Reset ratio	Typically 60 ms <95 ms <50 ms 0.97
Transient over-reach, any τ	<10 %
Inaccuracy: - Starting - Operating time at definite time function - Operating time at IDMT function	 ±3% of the set value or 5 mA secondary ±1% or ±30 ms ±5% or at least ±30 ms **)

*) EI = Extremely Inverse, NI = Normal Inverse, VI = Very Inverse, LTI = Long Time Inverse
MI= Moderately Inverse

**) The measuring range may limit the scope of inverse delays. See chapter 5.29 for details.

Overcurrent stages I>> and I>>> (50/51)

Pick-up current	0.10 – 20.00 x I_{GN} (I>>) 0.10 – 40.00 x I_{GN} (I>>>)
Definite time function: - Operating time - I>> - I>>>	 DT 0.04**) – 1800.00 s (step 0.01 s) 0.04**) – 300.00 s (step 0.01 s)
Start time Reset time Retardation time Reset ratio	Typically 60 ms <95 ms <50 ms 0.97
Transient over-reach, any τ	<10 %
Inaccuracy: - Starting - Operation time	 ±3% of the set value or 5 mA secondary ±1% or ±25 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Directional overcurrent stages I_{dir}> and I_{dir}>> (67)

Pick-up current	0.10 - 4.00 x I_{GN}
Mode	Directional/non-directional
Minimum voltage for the direction solving	0.1 V secondary
Base angle setting range	-180° to + 179°
Operation angle	±88°
Definite time function: - Operating time	DT 0.06*) – 300.00 s (step 0.02 s)
IDMT function: - Delay curve family - Curve type - Time multiplier k	 (DT), IEC, IEEE, RI, Prg EI, VI, NI, LTI, MI…depends on the family 0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time Reset time Retardation time Reset ratio Reset ratio (angle)	Typically 60 ms <95 ms <50 ms 0.95 2°
Transient over-reach, any τ	<10 %
Inaccuracy: - Starting - Angle - Operate time at definite time function - Operate time at IDMT function	 ±3% of the set value or ±0.5% of the rated value ±2° U>5 V ±30° U>0.1 V ±1% or ±30 ms ±5% or at least ±30 ms**)

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

**) The measuring range may limit the scope of inverse delays. See chapter 5.29 for details.

Directional overcurrent stages I_{dir}>>> and I_{dir}>>>> (67)

Pick-up current	0.10 – 20.0 x I_{GN}
Mode	Directional/non-directional
Minimum voltage for the direction solving	0.1 V secondary
Base angle setting range	-180° to + 179°
Operation angle	±88°
Definite time function: - Operating time	DT 0.06*) – 300.00 s (step 0.02 s)
Start time Reset time Retardation time Reset ratio Reset ratio (angle)	Typically 60 ms <95 ms <50 ms 0.95 2°
Transient over-reach, any τ	<10 %
Inaccuracy: - Starting (rated value IN= 1 .. 5A) - Angle - Operate time at definite time function	 ±3% of the set value or ±0.5% of the rated value ±2° U>5 V ±30° U>0.1 V ±1% or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Voltage restrained/controlled overcurrent stage I_V> (51V)

Settings: - I_V> - U_{X1}, U_{X2} - I_{Y1}, I_{Y2}	 0.50 – 4.00 x I_{GN} 0 – 150 % 0 – 200 %I_V>
Definite time function: - Operating time	 0.08*) – 300.00 s (step 0.02 s)
Start time Reset time Retardation time Reset ratio	Typically 60 ms <95 ms <50 ms 0.97
Transient over-reach, any τ	<10 %
Inaccuracy: - Starting - Operate time	 ±3% of set value ±1% or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Current unbalance stage I_2> (46)

Setting range:	2 – 70% (step 1%)
Definite time characteristic:	
- operating time	1.0 – 600.0s s (step 0.1)
Inverse time characteristic:	
- 1 characteristic curve	Inv
- time multiplier K_1	1 – 50 s (step 1)
- upper limit for inverse time	1 000 s
Start time	Typically 200 ms
Reset time	<450 ms
Reset ratio	0.95
Inaccuracy:	
- Starting	±1% - unit
- Operate time	±5% or ±200 ms

Stage is operational when all secondary currents are above 250 mA.

Thermal overload stage T> (49)

Overload factor:	0.1 – 2.40 x I_{GN} (step 0.01)
Alarm setting range:	60 – 99 % (step 1%)
Time constant Tau:	2 – 180 min (step 1)
Cooling time coefficient:	1.0 – 10.0 xTau (step 0.1)
Max. overload at +40 °C	70 – 120 %I_{GN} (step 1)
Max. overload at +70 °C	50 – 100 %I_{GN} (step 1)
Ambient temperature	-55 – 125 °C (step 1°)
Resetting ratio (Start & trip)	0.95
Inaccuracy:	
- operating time	±5% or ±1 s

Earth fault stage I_0> (50N/51N)

Input signal	I_0 (input X1-7 & 8) I_{02} (input X1-9 & 10) I_{0Calc} (= $I_{L1}+I_{L2}+I_{L3}$)
Setting range I_0>	0.005 … 8.00 When I_0 or I_{02} 0.05 … 20.0 When I_{0Calc}
Definite time function: - Operating time	DT 0.08**) – 300.00 s (step 0.02 s)
IDMT function: - Delay curve family - Curve type - Time multiplier k	 (DT), IEC, IEEE, RI Prg EI, VI, NI, LTI, MI…depends on the family *) 0.05 - 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time Reset time Reset ratio	Typically 60 ms <95 ms 0.95
Inaccuracy: - Starting - Starting (Peak mode) - Operating time at definite time function - Operating time at IDMT function.	 ±2% of the set value or ±0.3% of the rated value ±5% of the set value or ±2% of the rated value (Sine wave <65 Hz) ±1% or ±30 ms ±5% or at least ±30 ms **)

*) EI = Extremely Inverse, NI = Normal Inverse, VI = Very Inverse, LTI = Long Time Inverse
MI= Moderately Inverse

**) The measuring range may limit the scope of inverse delays. See chapter 5.29 for details.

Earth fault stages I_0>>, I_{02}>, I_{02}>> (50N/51N)

Input signal	I_0 (input X1-7 & 8) I_{02} (input X1-9 & 10) I_{0Calc} (= $I_{L1}+I_{L2}+I_{L3}$)
Setting range I_0>>	0.01 … 8.00 When I_0 or I_{02} 0.05 … 20.0 When I_{0Calc}
Definite time function: - Operating time	 0.08*) – 300.00 s (step 0.02 s)
Start time Reset time Reset ratio	Typically 60 ms <95 ms 0.95
Inaccuracy: - Starting - Starting (Peak mode) - Operate time	 ±2% of the set value or ±0.3% of the rated value ±5% of the set value or ±2% of the rated value (Sine wave <65 Hz) ±1% or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Directional intermittent transient earth fault stage I_{0INT}> (67NI)

Input selection for I_0 peak signal	I_{01} Connectors X1-7&8 I_{02} Connectors X1-9&10
I_0 peak pick up level (fixed)	0.1 x I_{0N} @ 50 Hz
U_0 pickup level	10 – 100 % U_{0N}
Definite operating time	0.12 – 300.00 s (step 0.02)
Intermittent time	0.00 – 300.00 s (step 0.02)
Start time	<60 ms
Reset time	<60 ms
Reset ratio (hysteresis) for U_0	0.97
Inaccuracy: - starting - time	 ±3% for U_0. No inaccuracy defined for I_0 transients ±1% or ±30 ms *)

*) The actual operation time depends of the intermittent behaviour of the fault and the intermittent time setting.

Directional earth fault stages $I_0\varphi$>, $I_0\varphi$>> (67N)

Pick-up current	0.005 - 8.00 x I_{0N} 0.05 … 20.0 When I_{0Calc}
Start voltage	1 – 50 %U_{0N}
Input signal	I_0 (input X1-7 & 8) I_{02} (input X1-9 & 10) I_{0Calc} (= $I_{L1}+I_{L2}+I_{L3}$)
Mode	Non-directional/Sector/ResCap
Base angle setting range	-180° to + 179°
Operation angle	±88° (10° - 170°)
Definite time function: - Operating time	 0.10**) – 300.00 s (step 0.02 s)
IDMT function: - Delay curve family - Curve type - Time multiplier k	 (DT), IEC, IEEE, RI Prg EI, VI, NI, LTI, MI…depends on the family *) 0.05 - 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time Reset time Reset ratio Reset ratio (angle)	Typically 60 ms <95 ms 0.95 2°
Inaccuracy: - Starting Uo&Io (rated value In= 1 .. 5A) - Starting Uo&Io (Peak Mode when, rated value Io_n= 1 .. 10A) - Starting U_0&I_0 (I_{0Calc}) - Angle - Operate time at definite time function - Operate time at IDMT function	 ±3% of the set value or ±0.3% of the rated value ±5% of the set value or ±2% of the rated value (Sine wave <65 Hz) ±3% of the set value or ±0.5% of the rated value ±2° (when U> 1V and I_0>5% of I_{0N} else ±20° ±1% or ±30 ms ±5% or at least ±30 ms **)

*) EI = Extremely Inverse, NI = Normal Inverse, VI = Very Inverse, LTI = Long Time Inverse
MI= Moderately Inverse

**) The measuring range may limit the scope of inverse delays. See chapter 5.29 for details.

12.3.2. Voltage protection

Overvoltage stages U>, U>> and U>>> (59)

Overvoltage setting range:	
- U>, U>>	50 - 150 %U_N **)
- U>>>	50 - 160 % U_N **)
Definite time characteristic:	
- operating time U>, U>>	0.08*) - 300.00 s (step 0.02)
- operating time U>>>	0.06*) - 300.00 s (step 0.02)
Starting time	Typically 60 ms
Resetting time U>	0.06 - 300.00 s (step 0.02)
Resetting time U>>, U>>>	<95 ms
Retardation time	<50 ms
Reset ratio	0.99 – 0.800 (0.1 – 20.0 %, step 0.1 %)
Inaccuracy:	
- starting	±3% of the set value **)
- operate time	±1% or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

**) The measurement range is up to 175 V. This limits the maximum usable setting when rated VT secondary is more than 100 V.

Volts/hertz over-excitation protection U_f> (24)

Pick-up setting range	100 – 200 %
Operating time	0.3 – 300.0 s
Start time Reset time Reset ratio	Typically 200 ms <450 ms 0.995
Inaccuracy: - Starting - Operating time at definite time function	 U < 0.5 % unit f < 0.05 Hz ±1 % or ±150 ms

Positive sequence undervoltage stages U_1<, U_1<< (27P)

Setting range	20 – 120% x U_{GN}
Definite time function: - Operating time	 0.08 *) – 300.00 s
Undervoltage blocking - Blocking time, when I< 1% x Ign	2 – 100% x U_{GN} (common for both stages) 0 – 30 s (common for both stages)
Start time Reset time Retardation time Reset ratio	Typically 60 ms <95 ms <50 ms 1.03
Inaccuracy: - Starting - Operating time	 ±3% of set value ±1% or ±30 ms

*) This is the total operational time including the fault detection time and operation time of the trip contacts.

NOTE! To make the relay trip after low voltage blocking, the positive sequence voltage has to go above the pick-up setting.

Undervoltage stage U<, U<<, U<<< (27)

Setting range	20 – 120%xU_N
Definite time function: - Operating time U< - Operating time U<< and U<<<	 0.08 *) – 300.00 s (step 0.02 s) 0.06 *) – 300.00 s (step 0.02 s)
Undervoltage blocking	0 – 80% x U_N
Start time	Typically 60 ms
Reset time for U< Reset time for U<< and U<<< Retardation time Reset ratio (hysteresis) Reset ratio (Block limit)	0.06 – 300.00 s (step 0.02 s) <95 ms <50 ms 1.001 – 1.200 (0.1 – 20.0 %, step 0.1 %) 0.5 V or 1.03 (3 %)
Inaccuracy: - starting - blocking - time	 ±3% of set value ±3% of set value or ±0.5 V ±1% or ±30 ms

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Zero sequence voltage stages U_0> and U_0>> (59N)

Zero sequence voltage setting range	1 – 60 %U_{0N}
Definite time function: - Operating time	 0.3 – 300.0 s (step 0.1 s)
Start time Reset time Reset ratio	Typically 200 ms <450 ms 0.97
Inaccuracy: - Starting - Starting UoCalc (3LN mode) - Operate time	 ±2% of the set value or ±0.3% of the rated value ±1 V ±1% or ±150 ms

100 % stator earth-fault protection U_{0f3}< (64F3)

Pick-up setting range	1 ... 50 %
Definite time function: - Operating time	 0.5 – 30.0 minutes
Start time Reset time Reset ratio	<2 s <4 s 1.05 *)
Fundamental low voltage block limit (U_{12} and U_{23})	Blocked when U_{12} and U_{23} < 65 % of nominal
Inaccuracy: - Starting - Operating time at definite time function	 ±1 % units ±1% or ±2 s

*) When pick-up setting is below 5%, reset value is less than set value +0,5 % unit

NOTE! The voltage measurement mode must be "2LL+U_0" when this protection stage is used.

12.3.3. Frequency protection

Overfrequency and underfrequency protection stages f>< and f>><<

Frequency measuring area	16.0 - 75.0 Hz
Current and voltage meas. range	45.0 – 65.0 Hz
Frequency stage setting range	40.0 – 70.0 Hz
Low voltage blocking	10 – 100 %Un *)
Definite time function:	
-operating time	0.10**) – 300.0 s (step 0.02 s)
Starting time	<100 ms
Reset time	<120 ms
Reset ratio (f> and f>>)	0.998
Reset ratio (f< and f<<)	1.002
Reset ratio (LV block)	Instant (no hysteresis)
Inaccuracy:	
- starting	±20 mHz
- starting (LV block)	3% of the set value or ±0.5 V
- operating time	±1% or ±30 ms

*) Suitable frequency area for low voltage blocking is 45 - 65 Hz. Low voltage blocking is checking the maximum of line to line voltages.

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

NOTE! f< if device restarts for some reason there will be no trip even if the frequency is below the set limit during the start up (Start and trip is blocked). To cancel this block, frequency has to visit above the set limit.

Underfrequency stages f< and f<<

Frequency measuring area	16.0 - 75.0 Hz
Current and voltage meas. range	45.0 – 65.0 Hz
Frequency stage setting range	40.0 – 64.0 Hz
Low voltage blocking	10 – 100 %U_{GN} *)
Definite time function:	
-operating time	0.10**) - 300.0 s (step 0.02 s)
Undervoltage blocking	2 – 100 %
Starting time	<100 ms
Reset time	<120 ms
Reset ratio	1.002
Reset ratio (LV block)	Instant (no hysteresis)
Inaccuracy:	
- starting	±20 mHz
- starting (LV block)	3% of the set value or ±0.5 V
- operating time	±1% or ±30 ms

*) Suitable frequency area for low voltage blocking is 45 - 65 Hz. Low voltage blocking is checking the maximum of line to line voltages.

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Rate of change of frequency (ROCOF) stage df/dt> (81R)

Setting range	0.2 - 10.0 Hz/s
Definite time function:	
-operating time	0.14*) – 10.00 s
Minimum delay (for inverse time delay	0.14 – 10.00 s
Start time	Typically 140 ms
Reset time	< operating time + 150 ms
Retardation time	<90 ms
Reset ratio	1
Inaccuracy:	
- starting	±0.05 Hz/s
- operating time	±1% or ±30 ms

*) The fastest operation time is more than specified, if the setting is less than 0.7 Hz/s. This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

12.3.4. Impedance and power protection

Under-impedance stages Z<, Z<< (21)

Pick-up setting range	0.05 – 2.00 xZ_N
Definite time function:	
- Operating time	0.08*) – 300.00 s (step 0.02 s)
Start time	Typically 60 ms
Reset time	<95 ms
Retardation time	<50 ms
Reset ratio	1.05
Inaccuracy:	
- Starting	±4 % of set value or ±0.01 x Z_N
- Operating time at definite time function	±1 % or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Under-excitation stage Q< (40)

Settings:	
- Q@P0%, Reactive power limit at P=0 %	-100 – 0 $\%xS_{GN}$
- Q@P80%, Reactive power limit at P=80 %	-100 – 0 $\%xS_{GN}$
Definite time function:	
- Operating time	0.08*) – 300.00 s (step 0.02 s)
Start time	Typically 60 ms
Reset time	0.06 – 300.00 s (step 0.02 s)
Retardation time	<50 ms
Reset ratio	0.98 (x S_{GN})
Inaccuracy:	
- Starting	±3% of set value or ±0.5% of S_{GN}
- Operating time	±1% or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Under reactance and loss of excitation stages X<, X<< (40)

Trip area radius setting range	0.05 ... 2.00 xZ_N
Resistive offset Ros	–2.00 ... +2.00 xZ_N
Reactive offset Xos	–2.00 ... +2.00 xZ_N
Definite time function: - Operating time	 0.08*) – 300.00 s (step 0.02 s)
Start time Reset time Reset ratio	<80 ms 0.08 – 300.00 s (step 0.02 s) 1.05
Inaccuracy: - Starting - Operating time at definite time function	 ±4 % of set value or ±0.01 x Z_N ±1 % or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Reverse power and under-power stages P<, P<< (32)

Pick-up setting range	–200.0 ... +200.0 %Pm
Definite time function: - Operating time	 0.3 – 300.0 s
Start time Reset time Reset ratio	Typically 200 ms <500 ms 1.05
Inaccuracy: - Starting - Operating time at definite time function	 ±3 % of set value or ±0.5 % of rated value ±1 % or ±150 ms

NOTE! When pick-up setting is +1 … +200% an internal block will be activated if max. voltage of all phases drops below 5% of rated.

12.3.5. Second harmonic function

2. Harmonic stage (51F2)

Settings: - Setting range 2.Harmonic - Operating time	 10 – 100 % 0.05 – 300.00 s (step 0.01 s)
Inaccuracy: - Starting	 ±1%- unit

NOTE! The amplitude of second harmonic content has to be at least 2% of the nominal of CT. If the moninal current is 5 A, the 100 Hz component needs to exceed 100 mA.

12.3.6. Fifth harmonic function

5. Harmonic stage I_{f5}> (51F5)

Settings: - Setting range 2.Harmonic - Operating time	 10 – 100 % 0.05 – 300.00 s (step 0.01 s)
Inaccuracy: - Starting	 ±2%- unit

NOTE! The amplitude of second harmonic content has to be at least 2% of the nominal of CT. If the moninal current is 5 A, the 250 Hz component needs to exceed 100 mA

12.3.7. Circuit-breaker failure protection

Circuit-breaker failure protection CBFP (50BF)

Relay to be supervised	T1 or T2 *)
Definite time function - Operating time	 0.1 – 10.0 s (step 0.1 s)
Reset time	<95 ms
Inaccuracy - Operating time	 ±20 ms

*) This setting is used by CB condition monitoring function, too.

12.3.8. Arc fault protection stages (option)

Arc protection stage ArcI> (50ARC), option

Setting range	0.5 - 10.0 x I_N
Arc sensor connection	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI
- Operating time (Light only)	13 ms
- Operating time (4xIset + light)	17ms
- Operating time (BIN)	10 ms
- Operating time (Delayed Arc L>)	0.01 – 0.15 s
- BO operating time	<3 ms
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	<85 ms
Reset ratio	0.90
Inaccuracy:	
- Starting	10% of the set value
- Operating time	±5 ms
- Delayed ARC light	±10 ms

Arc protection stage ArcI$_0$> (50NARC), option

Setting range	0.5 - 10.0 x I_N
Arc sensor connection	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI
- Operating time (Light only)	13 ms
- Operating time (4xIset + light)	17ms
- Operating time (BIN)	10 ms
- Operating time (Delayed Arc L>)	0.01 – 0.15 s
- BO operating time	<3 ms
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	<85 ms
Reset ratio	0.90
Inaccuracy:	
- Starting	10% of the set value
- Operating time	±5 ms
- Delayed ARC light	±10 ms

Arc protection stage $ArcI_{02}$> (50NARC), option

Setting range	0.5 - 10.0 x I_N
Arc sensor connection	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI
- Operating time (Light only)	13 ms
- Operating time (4xIset + light)	17ms
- Operating time (BIN)	10 ms
- Operating time (Delayed Arc L>)	0.01 – 0.15 s
- BO operating time	<3 ms
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	<85 ms
Reset ratio	0.90
Inaccuracy:	
- Starting	10% of the set value
- Operating time	±5 ms
- Delayed ARC light	±10 ms

12.4. Supporting functions

12.4.1. Disturbance recorder (DR)

The operation of disturbance recorder depends on the following settings. The recording time and the number of records depend on the time setting and the number of selected channels.

Disturbance recorder (DR)

Mode of recording:	Saturated / Overflow
Sample rate:	
- Waveform recording	32/cycle, 16/cycle, 8/cycle
- Trend curve recording	10, 20, 200 ms 1, 5, 10, 15, 30 s 1 min
Recording time (one record)	0.1 s – 12 000 min (must be shorter than MAX time)
Pre-trigger rate	0 – 100%
Number of selected channels	0 – 12

12.4.2. Inrush current detection (68)

Settings:	
- Setting range 2.Harmonic	10 – 100 %
- Operating time	0.05** – 300.00 s (step 0.01 s)

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

12.4.3. Transformer supervision

Current transformer supervision

Pick-up current	0.00 – 10.00 x I_N
Definite time function: - Operating time	DT 0.06 – 600.00 s (step 0.02 s)
Reset time Reset ratio Imax> Reset ratio Imin<	<60 ms 0.97 1.03
Inaccuracy: - Activation - Operating time at definite time function	 ±3% of the set value ±1% or ±30 ms

Voltage transformer supervision

Pick-up setting U2>	0.0 – 200.0 %
Pick-up setting I2<	0.0 – 200.0 %
Definite time function: - Operating time	DT 0.06 – 600.00 s (step 0.02 s)
Reset time Reset ratio	<60 ms 3% of the pick-up value
Inaccuracy: - Activation U2> - Activation I2< - Operating time at definite time function	 ±1%-unit ±1%-unit ±1% or ±30 ms

12.4.4. Voltage sags & swells

Voltage sag limit	10 – 120 %
Voltage swell limit	20 – 150 %
Definite time function: - Operating time	DT 0.08 – 1.00 s (step 0.02 s)
Low voltage blocking Reset time Reset ration: - Sag - Swell - Block limit	0 – 50 % <60 ms 1.03 0.97 0.5 V or 1.03 (3 %)
Inaccuracy: - Activation - Activation (block limit) - Operating time at definite time function	 ±0.5 V or 3% of the set value ±5% of the set value ±1% or ±30 ms

If one of the phase voltages is below sag limit and above block limit but another phase voltage drops below block limit, blocking is disabled.

12.4.5. Voltage interruptions

Voltage low limit (U1)	10 – 120 %
Definite time function: - Operating time	DT <60 ms (Fixed)
Reset time Reset ratio:	<60 ms 1.03
Inaccuracy: - Activation	 3% of the set value

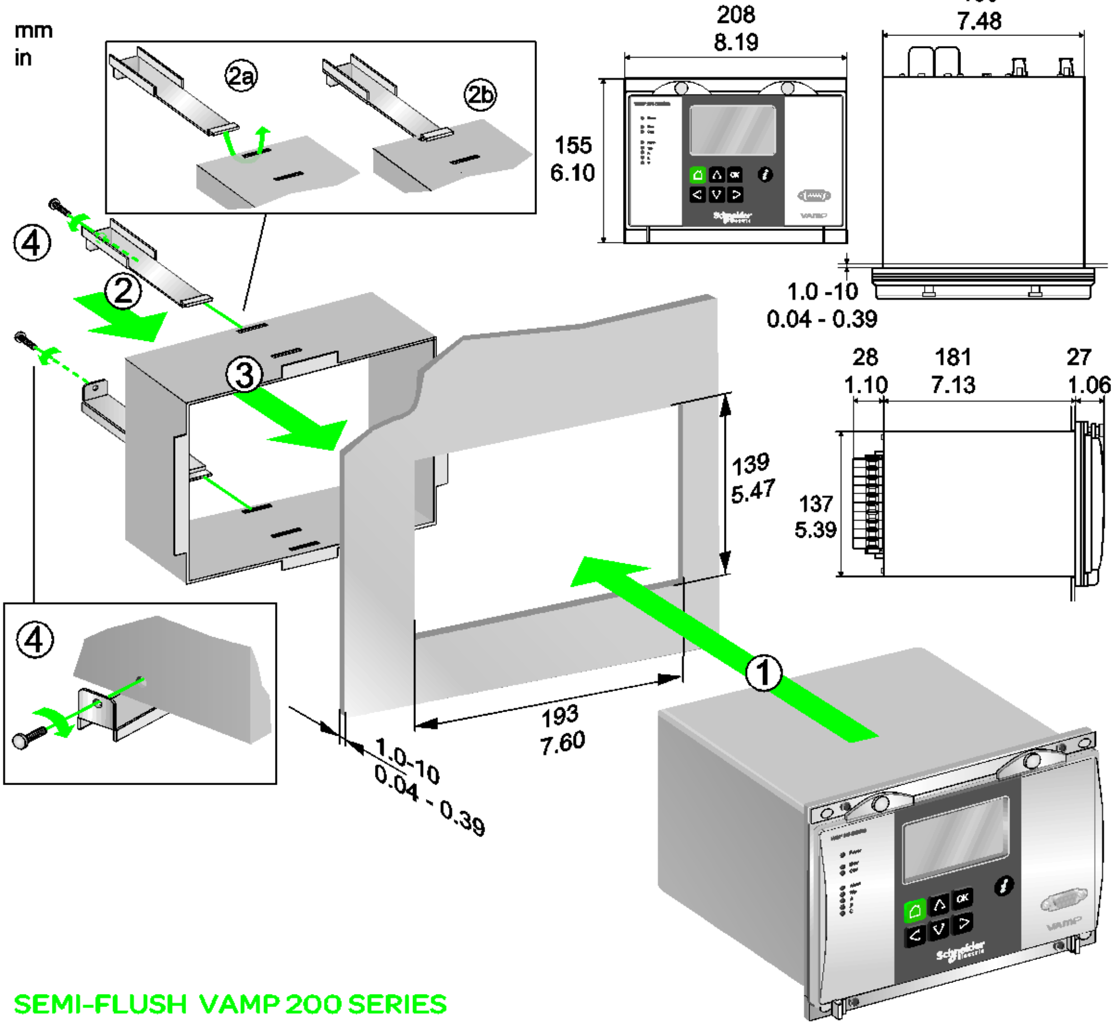
13. Abbreviations and symbols

ANSI	American National Standards Institute. A standardization organisation.
CB	Circuit breaker
CBFP	Circuit breaker failure protection
cosφ	Active power divided by apparent power = P/S. (See power factor PF). Negative sign indicates reverse power.
CT	Current transformer
CT_{PRI}	Nominal primary value of current transformer
CT_{SEC}	Nominal secondary value of current transformer
Dead band	See hysteresis.
DI	Digital input
DO	Digital output, output relay
DSR	Data set ready. An RS232 signal. Input in front panel port of VAMP relays to disable rear panel local port.
DST	Daylight saving time. Adjusting the official local time forward by one hour for summer time.
DTR	Data terminal ready. An RS232 signal. Output and always true (+8 Vdc) in front panel port of VAMP relays.
FFT	Fast Fourier transform. Algorithm to convert time domain signals to frequency domain or to phasors.
Hysteresis	I.e. dead band. Used to avoid oscillation when comparing two near by values.
I_{SET}	Another name for pick up setting value I>
I_{0SET}	Another name for pick up setting value I_0>
I_{01N}	Nominal current of the I_{01} input of the relay
I_{02N}	Nominal current of the I_{02} input of the relay
I_{0N}	Nominal current of I_0 input in general
I_{GN}	Nominal current of the protected device
I_N	Nominal current. Rating of CT primary or secondary.
IEC	International Electrotechnical Commission. An international standardization organisation.
IEEE	Institute of Electrical and Electronics Engineers
IEC-103	Abbreviation for communication protocol defined in standard IEC 60870-5-103
LAN	Local area network. Ethernet based network for computers and relays.

Latching	Output relays and indication LEDs can be latched, which means that they are not released when the control signal is releasing. Releasing of lathed devices is done with a separate action.
NTP	Network time protocol for LAN and WWW
P	Active power. Unit = [W]
PF	Power factor. The absolute value is equal to cosφ, but the sign is '+' for inductive i.e. lagging current and '–' for capacitive i.e. leading current.
P_M	Nominal power of the prime mover. (Used by reverse/under power protection.)
PT	See VT
pu	Per unit. Depending of the context the per unit refers to any nominal value. For example for overcurrent setting 1 pu = $1xI_{GN}$.
Q	Reactive power. Unit = [var] acc. IEC
RMS	Root mean square
S	Apparent power. Unit = [VA]
S_{GN}	Nominal power of the protected device
SNTP	Simple Network Time Protocol for LAN and WWW
TCS	Trip circuit supervision
THD	Total harmonic distortion
U_{0SEC}	Voltage at input U_c at zero ohm earth fault. (Used in voltage measurement mode "2LL+Uo")
U_A	Voltage input for U_{12} or U_{L1} depending of the voltage measurement mode
U_B	Voltage input for U_{23} or U_{L2} depending of the voltage measurement mode
U_C	Voltage input for U_{31} or U_0 depending of the voltage measurement mode
U_{GN}	Nominal voltage of the protected device
U_N	Nominal voltage. Rating of VT primary or secondary
UTC	Coordinated Universal Time (used to be called GMT = Greenwich Mean Time)
VT	Voltage transformer i.e. potential transformer PT
VT_{PRI}	Nominal primary value of voltage transformer
VT_{SEC}	Nominal secondary value of voltage transformer
WWW	World wide web $\approx$ internet

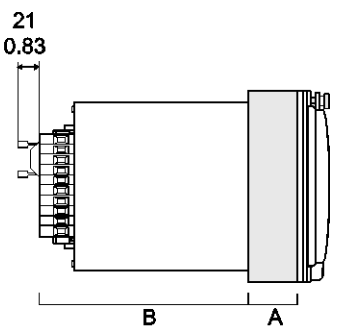
14. Construction

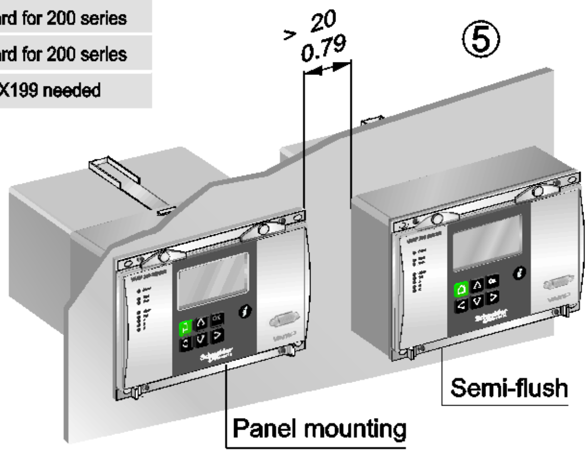
PANEL MOUNTING VAMP 200 SERIES



SEMI-FLUSH VAMP 200 SERIES

Raising frame	A	B	Fixing bracket
VYX076	40 mm / 1.57 in	69 mm / 6.65 in	Standard for 200 series
VYX077	60 mm / 2.36 in	149 mm / 5.87 in	Standard for 200 series
VYX233	100 mm / 3.94 in	109 mm / 4.29 in	2 x VYX199 needed





15. Order information

When ordering, please, state the ordering code:

VAMP 210 ORDERING CODE

V 210 - □□□□□□ -

Nominal current [A]
- **1** = 1A
- **5** = 5A

Nominal earth-fault currents I_{01} & I_{02} [A]
- **A** = 5A & 5A
- **B** = 5A & 1A
- **C** = 1A & 5A
- **D** = 1A & 1A

Frequency [Hz]
- **7** = Standard relay

Supply voltage [V]
- **A** = 40.. 265Vac/dc
- **B** = 18.. 36Vdc
- **C** = 40.. 265Vac/dc + ARC Protection
- **D** = 18.. 36Vdc + ARC Protection
- **E** = 40.. 265Vac/dc + DI19, DI20 Optional
- **F** = 18.. 36Vdc + DI19, DI20 Optional

Optional hardware
- **A** = None
- **B** = Plastic/Plastic serial fibre interface
- **C** = Profibus interface
- **D** = RS 485 interface (4-wire)
- **E** = Glass/Glass serial fibre interface
- **F** = Rx Plastic/Tx Glass serial fibre interface
- **G** = Rx Glass/Tx Plastic serial fibre interface
- **H** = RJ-45 10Mbps ethernet interface
- **M** = RJ-45 10Mbps ethernet inc. IEC 61850
- **O** = LC 100 Mbps ethernet fibre interface inc. IEC 61850
- **P** = RJ-45 100Mbps ethernet interface inc. IEC 61850
- **R** = 2 x LC 100 Mbps ethernet fibre interface inc. IEC 61850
- **S** = 2 x RJ-45 100 Mbps ethernet interface inc. IEC 61850

Analog Outputs & firmware
- **A** = None, version 3 firmware (#
- **C** = None, version 6 firmware (*
- **D** = 4 pcs, version 6 firmware (*
- **E** = None, standard firmware
- **F** = 4 pcs, standard firmware

See Chapter 16 Firmware revision history

Ingress protection rating
- = IP30 (default)
- **I** = IP54 (option)

Note:

(* Optional hardware, A-H available

(# Optional hardware, A-G available

Accessories :

Order Code	Explanation	Note
VEA3CGi	External ethernet interface module	
VPA3CG	Profibus interface module	
VSE001PP	Fiber optic Interface Module (plastic - plastic)	
VSE002	RS485 Interface Module	
VSE003	RS485 Interface Module, Ext I/O interface	
VSE009	External DeviceNet interface module	
VIO 12 AB	RTD Module, 12pcs RTD inputs, RS 485 Communication (24-230 Vac/dc)	
VIO 12 AC	RTD/mA Module, 12pcs RTD inputs, PTC, mA inputs/outputs, RS232, RS485 and Optical Tx/Rx Communication (24 Vdc)	
VIO 12 AD	RTD/mA Module, 12pcs RTD inputs, PTC, mA inputs/outputs, RS232, RS485 and Optical Tx/Rx Communication (48-230 Vac/dc)	
VX003-3	RS232 programming cable (Vampset, VEA 3CGi)	Cable length 3m
VX004-M3	TTL/RS232 converter cable (PLC, VEA 3CGi)	Cable length 3m
VX007-F3	TTL/RS232 converter cable (VPA 3CG)	Cable length 3m
VA 1 DA-6	Arc Sensor	Cable length 6m
VAM 16D	External LED module	Disables rear local communication
VYX076	Raising Frame for 200-serie	Height 40mm
VYX077	Raising Frame for 200-serie	Height 60mm
VYX233	Raising Frame for 200-serie	Height 100mm
V200WAF	V200 wall aseembly frame	
VM690/230	3 Phase Nominal Voltage Matching Transformer	690V->230V , 400V->110V

16. Revision history

Manual revision history

Manual version	Description
V210/EN M/A011	The first version

Firmware revision history

Firmware version	Description
3.66	Non-volatile value storage (E^2PROM) updated.
3.68	Info-display v. spontaneous alarm-display conflict updated.
6.13	A major update. Older versions of VAMPSET parameter files are not compatible and must NOT be used! Numerous new features has been added: • several new protection stages • two setting groups for protection stages • temperature measurement and supervising using external Modbus modules • digital I/O extension using external Modbus modules. • user's programmable logic • user configurable interactive mimic display • language support (Latin alphabet) • IEC 60870-5-103, DNP 3.0 communication protocols • Supported for internal Ethernet adaptor (See Communication interface “H” in Chapter 15. Order information).
6.21	I0φ > sector mode characteristics improved. IEC 60870-5-101 added.
6.62	Uof3< correction. Unit transformer correction. Transient Intermittent (67NI) protection function added. RMS mode to I> added. Programmable curve "Operation delay" setting extended. Data points added to DNP3.0 and IEC 60870-5-101 protocols. Protocol menus visible in Vampset only if protocol is selected into use to a port. Corrections and additions to IEC 60870-5-101, DNP 3.0, Profibus and Modbus (slave and TCP) protocols. DeviceNET protocol support added. DCF-77 time syncronisation support added.

6.71	Phase voltage and power measurement corrections. Synchrocheck correction in voltage mode "2LL/Ly". Second harmonics stage added. Data points added to DNP3.0,IEC 60870-5-101 and Modbus (slave and TCP) protocols RMS mode added and "Operation delay" setting extended for I>>. Transient Intermittent (67NI) protection function improvements. "Operation delay" min setting reduced.
10.38	First release with new CPU.Older versions of VAMPSET parameter files are not compatible with 10.x firmware. Native IEC61850 support including GOOSE added. DeviceNET protocol support added. UTF-8 support for local HMI panel (Russian) added. RTD Inputs- Quick Setup support added for VIO 12Ax EthernetIP added. Improvements added to DNP3.0,IEC 60870-5-101 protocols.
10.45	NVRAM event buffer size is user parameter.
10.48	Support for HMS Profibus solution. IRIG-B003.
10.49	Polarity added for relays. Read/write MAC address to/from EEPROM with new chip. IEC61850: DI counters are reported via deadband calculation.
10.51	SC fault distance added to IEC103 map
10.56	Uo setting grange of IoDir stages changed from 1...20% to 1...50%.
10.58	New features in IEC 61850 added. Outputs vef files with suomi & russian language packets.
10.65	100 Mbps option card support.
10.67	Default font sizes changed. Io>> minimum delay setting changed to 0.05s with 0.01s step. Popup window added for language packet init. EF items: EFDX, EFDFph, EFctr and EFDFltDist added to IEC103.
10.68	Ethernet/IP and DeviceNet identity info changes.
10.74	Lower 3rd harmonic limit for U_0f3<. I> and I_0> - I_0>>>> -stages with faster operation time.
10.85	Virtual output events added
10.106	GOOSE supervision signals added. Automatic LED latch release added Disturbance recorder full event added
10.108	Use of recorder memory in percents added Various additions to IEC 61850
10.113	U12y voltage measurement to IEC 60870-5-101 protocol **NOTE! Vampset version 2.2.59 required.**

10.116	IP and other TCP parameters are able to change without reboot. Logic output numbering is not changed when changes are made in the logic. **NOTE! Vampset version 2.2.97 required.**
10.118	Enable sending of analog data in GOOSE message Day light saving (DST) rules added for system clock. HMI changes: - Order of the first displays changed, 1.measurement, 2. mimic, 3. title - timeout does not apply if the first 3 displays are active.

Customers Care Center
http://www.schneider-electric.com/ccc

Schneider Electric
35 rue Joseph Monier
92506 Rueil-Malmaison
FRANCE
Phone: +33 (0) 1 41 29 70 00
Fax: +33 (0) 1 41 29 71 00
www.schneider-electric.com

Publication version: V210/EN M/A011

Publishing: Schneider Electric
12/2012